TM 1-250

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

FIXED WING FLIGHT

> This copy is a reprint which includes current pages from Changes 1 and 2.

HEADQUARTERS, DEPARTMENT OF THE ARMY
MAY 1968

CHANGE }

No. 3 }

FIXED WING FLIGHT

TM 1–250, 22 May 1968, is changed as follows:

1. New or changed material is indicated by a star.

2. Remove old pages and insert new pages as indicated below.

Remove old pages	*Insert new pages*
B–1 through B–5	B–1 through B–5

3. File this change page in the front of manual for reference purposes.

By Order of the Secretary of the Army:

W. C. WESTMORELAND,
General, United States Army,
Chief of Staff

Official:
VERNE L. BOWERS,
Major General, United States Army,
The Adjutant General.

Distribution:

To be distributed in accordance with DA Form 12–31, (qty rqr block no. 29) Operator and Crew maintenance requirements for all Fixed Wing aircraft.

CHANGE }

No. 2 }

FIXED WING FLIGHT

TM 1–250, 22 May 1968, is changed as follows:

1. New or changed material is indicated by a star.

2. Remove old pages and insert new pages as indicated below.

Remove old pages —	*Insert new pages —*
i and ii	i and ii
1–1 and 1–2	1–1 and 1–2
2–3 and 2–4	2–3 and 2–4
3–3 and 3–4	3–3 and 3–4
7–7 and 7–8	7–7 and 7–8
7–13 and 7–14	7–13 and 7–14
10–1 and 10–2	10–1 and 10–2
11–5 and 11–6	11–5 and 11–6
A–1 and A–2	A–1 and A–2
B–1 and B–2	B–1 and B–2
C–1 through C–9	
G–1 and G–2	G–1 and G–2

3. Retain this change sheet in the front of manual for future reference.

By Order of the Secretary of the Army:

W. C. WESTMORELAND,
General, United States Army,
Chief of Staff.

Official:
  KENNETH G. WICKHAM,
  Major General, United States Army,
  The Adjutant General.

DISTRIBUTION:
To be distributed in accordance with DA Form 12–31, Section I (qty rqr block No. 29) operator and crew maintenance requirements for all fixed wing aircraft.

CHANGE }

NO. 1 }

FIXED WING FLIGHT

TM 1-250, 22 May 1968, is changed as follows:

On page 6-3, top of the second column, the formula should include the radical sign, to read:

$$V\ minimum = \sqrt{\dfrac{W}{C_L\ maximum \times \dfrac{D}{2} \times A}}$$

which may be simplified to:

$$V\ minimum = 1.414\ \sqrt{\dfrac{W}{C_L DA}}$$

By Order of the Secretary of the Army:

W. C. WESTMORELAND,
General, United States Army,
Chief of Staff.

Official:

KENNETH G. WICKHAM,
Major General, United States Army,
The Adjutant General.

Distribution:
To be distributed in accordance with DA Form 12-31, Section I (qty rqr block no. 29) operator and crew maintenance requirements for all fixed wing aircraft.

TECHNICAL MANUAL }

No. 1-250 }

FIXED WING FLIGHT

*This manual supersedes TM 1-250, 25 September 1957, including all changes.

CHAPTER 1
GENERAL

—1. Purpose

This manual explains general principles concerning the operation of airplanes in accomplishing the Army aviation mission. The principles included are of equal importance to aviation students and rated aviation personnel.

1-2. Scope

a. Chapters 1 through 6 explain basic airplane aerodynamics and flight techniques. Chapters 7 through 9 cover the mechanics of flight maneuvers, providing the experienced aviator a basis for checking his proficiency. Chapter 10 explains major flight characteristics of a twin-engine airplane, and chapter 11 explains advanced methods of flying an airplane to accomplish the Army aviation mission. A glossary lists and defines specialized terms used in this manual.

b. Information in this manual is general and applicable, in part, to all airplanes. Specific flight procedures and practices for individual airplanes are found in the applicable operator's manual. Additional references are given in appendix A.

c. The material presented herein is applicable to nuclear or nonnuclear warfare.

★1-3. Report of Equipment Publication Improvements

Users of this publication are encouraged to submit recommended changes and comments to improve the publication. Comments should be keyed to the specific page, paragraph, and line of the text in which the change is recommended. Reasons will be provided for each comment to insure understanding and complete evaluation. Comments should be prepared using DA Form 2028 (Recommended Changes to Publications) and forwarded direct to the Commandant, United States Army Aviation School, ATTN: AJRDL–L, Fort Rucker, Ala. 36360.

CHAPTER 2
BASIC PHYSICAL LAWS APPLICABLE TO AERODYNAMICS

Section I. PHYSICAL LAWS

2-1. General

An aviator does not need to know all physical laws related to aero-dynamics as does an aeronautical engineer. He must, however, have some knowledge of these laws to understand aerodynamics as applied to his airplane and its control. This knowledge is best gained through application of basic laws to demonstrate how forces which affect the airplane or its various parts cause specific actions and reactions in flight.

2-2. Force, Pressure, Work, and Power

a. Force. Force is the effect of any action which changes the state of motion or position of a body; i.e., any action which tends to produce, retard, or oppose motion. A force has three characteristics—magnitude, direction, and point of application. It may be referred to as a push or a pull on a body that tends to produce motion or equilibrium. For example, an airplane in straight and level flight is acted on by the lift force of the wings opposed by the downward force of gravity and the thrust force of the engine opposed by the drag force of air friction. When these forces are balanced, the airplane is in equilibrium and moves ahead at constand speed with no acceleration.

b. Pressure. Pressure is force per unit of area and usually is measured in pounds per square inch. *For example,* if the base of a suitcase has an area of 100 square inches and weighs 100 pounds, the pressure of the suitcase on the area will be 100 pounds divided by 100 square inches, or 1 pound per square inch.

$$\text{Pressure} = \frac{\text{Total Force}}{\text{Area Acted Upon}}; \text{ or } P = \frac{F}{A}$$

c. Work. Work is the exertion of a force over a given distance expressed in foot-pounds. The time required to do the work is not a consideration. For example, if a 50-pound weight is raised 10 feet, 500 foot-pounds of work has been accomplished.

$$W = F \times D$$

Likewise, if a roller is placed under the weight so that only 15 pounds of force is required to move it along the floor, 150 foot-pounds of work is done in moving it a distance of 10 feet.

d. Power. Power is work accomplished in a given time, and is expressed in foot-pounds per second.

$$\text{Power} = \frac{\text{Force} \times \text{Distance}}{\text{Time}} = \frac{\text{Work}}{\text{Time}}$$

Power is also equal to force times the velocity at which it moves. Horsepower is an arbitrary unit of power equal to 550 foot-pounds per second.

2-3. Energy

Energy is the ability to do work. It is measured in the same units as work and is of two types—*potential* and *kinetic.*

a. Potential Energy. Potential energy is that stored energy in a body which may be released to do work at some future time. Bodies containing potential energy are a suspended weight, water stored behind a dam, gasoline or a storage battery (chemical energy), and compressed air or other gas (pressure energy). A suspended weight of a 2,000-pound airplane at an altitude of 2,000 feet above the terrain contains 4,000,000 foot-pounds of potential energy.

$$E = W \times D$$

b. Kinetic Energy. Kinetic energy is energy of motion and refers to the ability of a body in motion to do work on another body. If the

2,000-pound airplane in *a* above is moving at the rate of 160 feet per second, it also possesses 800,000 foot-pounds of kinetic energy due to its motion.

2-4. Speed and Velocity

Speed and velocity are frequently used interchangeably, but in aerodynamics they are distinguished. Speed is determined by distance traveled in an interval of time, *regardless of direction.* Velocity is speed *in a certain stated direction;* it is the amount of displacement of a body divided by the time required for this displacement.

2-5. Acceleration

Acceleration is the change in velocity per unit of time. It results from unbalanced forces acting on a body. *For example,* the downward force of gravity acting on a ball falling in space accelerates it at a rate of about 32 feet per second (disregarding air friction).

2-6. Laws of Motion

Newton's three laws of motion are *inertia. acceleration,* and *action-reaction.*

a. The first law (inertia) states that a body at rest tends to remain at rest, and a body in motion tends to remain in motion at the same speed and in the same direction until affected by some external force. Nothing in nature starts or stops without an outside force to bring about or prevent this motion. Hence, the force with which a body offers resistance to change is called the force of inertia.

b. The second law (acceleration) asserts that the force required to produce a change in motion of a body is directly proportional to its mass and the rate of change in its velocity. Acceleration may be due to an increase or a decrease in velocity, although deceleration is commonly used to indicate a decrease.

c. The third law (action-reaction) states that to every action there is an equal and opposite reaction. If a force acts to change the state of motion of a body, the body offers a resistance equal and directly opposite to the force.

Section II. VECTORS

2-7. Vector and Scalar Quantities

A vector quantity is a graphic representation of a force and shows both the magnitude and direction of the force. Velocity is a vector quantity. It specifies a certain amount of speed in a certain direction. Speed is called a *scalar* quantity (point of a scale) since it represents only magnitude. When an object is being acted upon by two or more forces, the combined effect of these forces may be represented by the use of vectors. In representing a vector quantity, a directed line segment with an arrow at the end is used. The arrow indicates the direction in which the force is acting. The length of the line segment in relation to a given scale represents the magnitude of the vector. The vector, therefore, is drawn in relation to a reference line. The magnitude is drawn to whatever scale is most convenient to the specific problem (fig. 2-1).

2-8. Vector Solutions

Individual force vectors are useful in analyzing conditions of flight. In the air, the chief concern is with the resultant, or combined effects, of the several component forces acting on an airplane. Three methods of solving for resultants are—

a. Parallelogram. A parallelogram contains two vectors, and lines are drawn parallel to these vectors to determine the resultant mean. When two tugboats are pushing a barge with equal force, the barge will move forward in a direction that is a mean to the direction of both tugboats (fig. 2-2).

b. Polygon Vector Solution. When more than two forces are acting in different directions, the resultant may be found by using a polygon vector solution. In the solution shown in figure 2-3, one force is acting at 090° with a force of 180 pounds; second force is acting
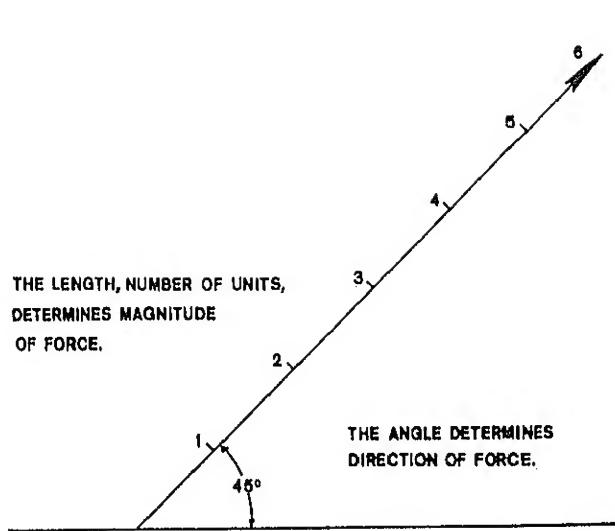
Figure 2-1. Vector diagram.
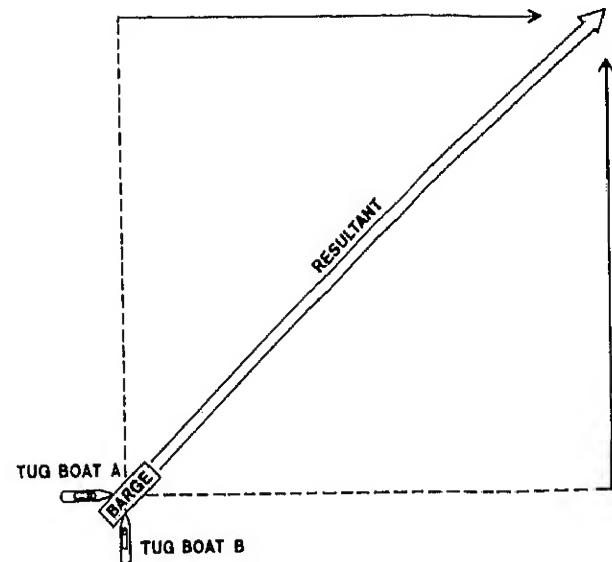
Figure 2-2. Resultant by parallelogram.

at 045° with a force of 90 pounds; the third force is acting at an angle of 315° with a force of 120 pounds. To determine the resultant, draw the first vector from a point beginning at 0 (fig. 2–3) and follow it with the remaining vectors, consecutively. The resultant is drawn from the point of start (a) to the ending of the final vector (C).

c. Triangle of Vectors.

(1) A triangle of vectors is a simplified and special form of a polygon vector solution which involves only two vectors and their re-sultant. It is the most commonly used vector solution in navigating.

(2) To form a triangle of vectors, draw two vectors and connect them with a resultant line of vector. In this way, calculations may be made for drift and groundspeed. In figure 2–4, an aircraft is heading 078° with a true air-speed of 100 knots. Wind direction is from the northeast at 30 knots. By drawing a vector for each of these known velocities and drawing a connecting line between the ends, a resultant velocity is determined.
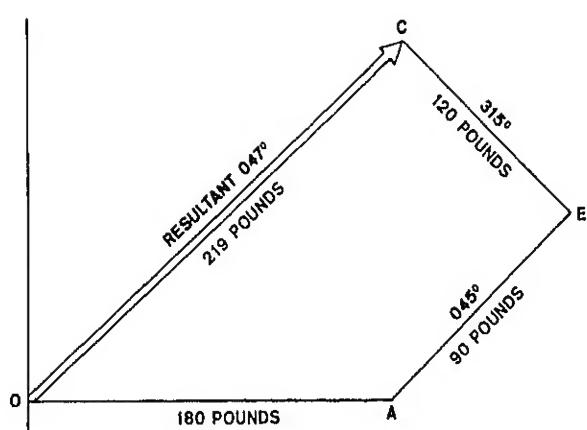
Figure 2–3. Resultant by polygon.

★Figure 2–4. Resultant by triangulation.

CHAPTER 3

PRINCIPLES OF AIRFOILS AND FORCES ACTING ON AN AIRCRAFT IN FLIGHT

Section I. PRINCIPLES OF AIRFOILS

3-1. Aerodynamics

Aerodynamics is that branch of dynamics that concerns the motion of air and other gases or the forces acting on objects in motion through the air (gases). In effect, aerodynamics is concerned with—the object (the airplane), the movement (the relative wind), and the air (the atmosphere).

3-2. Bernoulli's Theorem

The scientist Bernoulli discovered that the total energy of a system remains unchanged (constant). If one element of the energy system increases, another element decreases to counterbalance it; thus, when the energy of motion increases, the energy of pressure decreases. This theorem readily is seen by use of

AIRFLOW INLET

VENTURI THROAT

AIRFLOW OUTLET

ATMOSPHERIC PRESSURE 14.7 POUNDS PER SQUARE INCH

PRESSURE GAGES

14.70   14.67   14.63   14.54   14.63   14.67   14.70
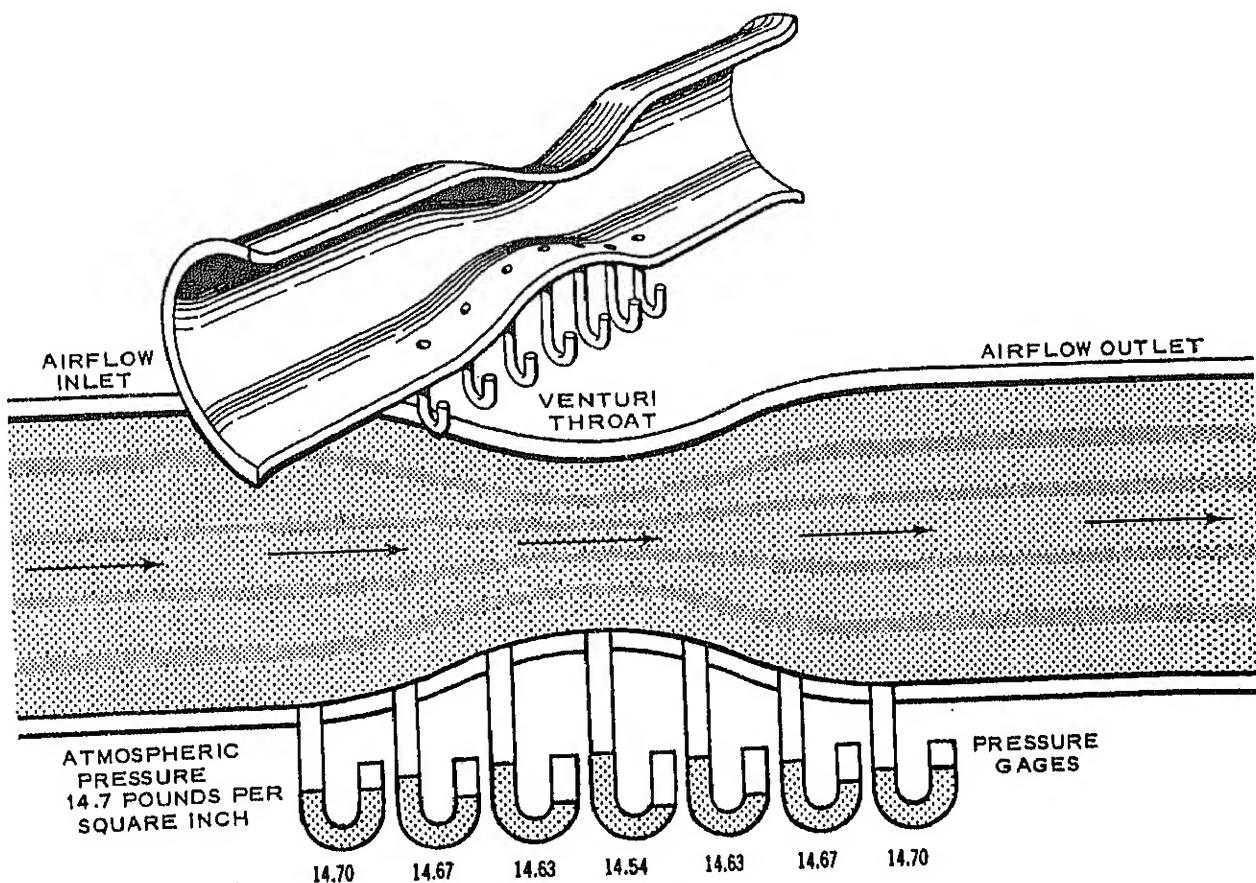
Figure 3-1. Venturi tube.
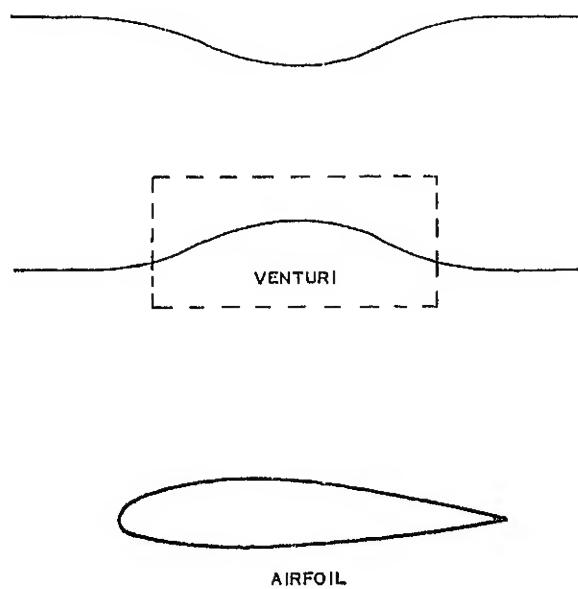
Figure 3-2. Comparison of airfoil and venturi tube.

a venturi tube (fig. 3-1). If the same amount of air that enters the tube is also going to leave it, then the velocity of the air must increase while passing the neck of the venturi. As the velocity increases, the air has less time in which to push against the sides of the tube, thereby exerting less pressure. Since there is no change of velocity of the air about the open end of the tube, there is no change in pressure. The differential pressure on the ends of the tubes attached to the venturi causes the fluid to move toward the end of the tube that has the least pressure.

3-3. Design of an Airfoil

The upper and lower surfaces of an airfoil may differ in total length, the upper surface usually being the longer. Air passing over the upper surface can be compared to the lower half of a venturi tube (fig. 3-2). This air must increase its velocity since it has a greater distance to travel; therefore, pressure on top of the airfoil is decreased. Air passing under the bottom of the airfoil has less distance to travel, so the velocity of the air is not as great as over the top; therefore, more pressure is present on the lower surface. Also, the lower surface in normal flight moves at an angle to the relative wind, causing the wind (or air) to strike the surface and produce some impact pressure. The reduced pressure above and increased pressure beneath the airfoil produces the "resultant aerodynamic force."

Section II. FORCES ACTING ON AN AIRCRAFT IN FLIGHT

3-4. Lift and Weight

a. *Lift.* Lift (fig. 3-3) is a component of the total aerodynamic force on an airfoil and acts perpendicular to the relative wind. This force acts through the center of lift, which is the mean of all centers of pressure. Its magnitude varies proportionately with airspeed, air density, shape and size of the airfoil, and angle of attack. In straight and level flight, it is equal and opposite to the weight component.

b. *Weight.* Weight is the force exerted by an airplane from the pull of gravity. It acts on an airplane through the center of gravity. The magnitude of this force changes only with a change in gross weight.

3-5. Thrust and Drag

a. *Thrust.* Thrust is the force that drives an airplane forward through the air. It is produced by a rotating propeller, jet engine, or other propulsive device.

b. *Drag.* Drag is the force produced by the resistance of the air on an object passing
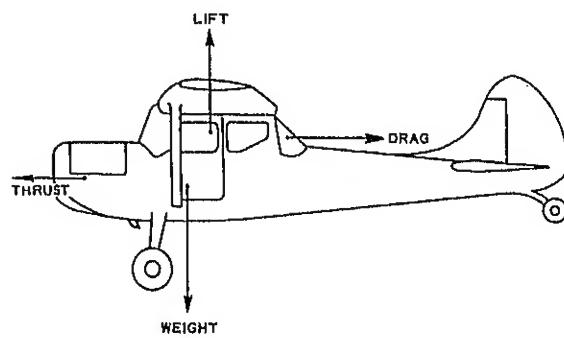
Figure 3-3. Forces and their centers in flight.

through it. In unaccelerated flight, it is equal and opposite to thrust. Drag may be divided into two main types—*induced* and *parasite*.

(1) Induced drag is that part of the total drag induced by the airflow about the lifting surfaces.

(2) Parasite drag is that drag created by the entire airplane, excluding induced drag. It is caused by protrusions (e.g., hinges and landing gear), rough surfaces of the airplane, and the impact of air on the frontal surfaces of the airplane.

3–6. Centrifugal Force

Centrifugal force is produced by an object moving in a circular path. The force acts toward the outside of the circle or turn. It acts on an airplane during all turns, regardless of the plane of the turn.

Section III. FACTORS AFFECTING LIFT AND DRAG

3–7. Equations

★Important factors influencing lift and drag are the shape and area of the airfoil, angle of attack, air density, and airspeed. A change in any of these factors affects the relationship of lift and drag. This is best seen through use of the following equations:

   a. *Lift Equation.*

$$L = C_L \times \frac{D}{2} \times A \times V^2$$

   L = lift
   C_L = Coefficient of lift
   D = density of the air in slugs per cubic foot
   A = total wing area in square feet
   V = airspeed in feet per second

   b. *Drag Equation.*

$$d = C_D \times \frac{D}{2} \times A \times V^2$$

   d = drag
   C_D = coefficient of drag
   D = density of the air in slugs per cubic foot
   A = total wing area in square feet
   V = airspeed in feet per second

   Note. C_L is the amount of weight in pounds that 1 square foot of wing area will lift at a speed of 1 foot per second, and C_D is the amount of drag in pounds that 1 square foot of wing area will create at a speed of 1 foot per second. These values for various angles of attack of a given airfoil are found in wind tunnel tests.

3–8. Effect of Airfoil Shape and Angle of Attack

   a. Two factors that most affect the coefficients of lift and drag of an airfoil are the shape, as established by the manufacturer, and the angle of attack, which is controlled by the pilot. As the length of the upper camber is increased, lift is also increased (to a certain point). If the length is further increased, the airflow will separate from the airfoil, causing a loss of lift. But as lift is increased, so is drag. Therefore, the airfoil is designed to produce the most lift and least drag at the designed normal weight and speed.

   b. By changing the pitch attitude or by the use of flaps the pilot can change the angle of attack. This, in effect, changes the upper camber of the airfoil and the differential pressure. Figure 3–4 shows how lift and drag increase with the angle of attack. The third line shows how the lift-drag ratio varies with different angles of attack.

3–9. Effect of Air Density, Wing Area, and Airspeed

   a. *Air Density.* Density is the weight of an object per unit volume and differs from pressure in that pressure is force per unit area. Density is directly affected by temperature, pressure, and humidity. Since density affects lift—temperature, pressure, and humidity also affect lift. An increase in temperature or humidity or a decrease in pressure will cause density to decrease, thereby causing lift to decrease. To sustain level flight when these conditions exist, the pilot must increase either the angle of attack or the airspeed.

   b. *Wing Area.* Wing area affects lift and drag directly. If two wings have the safe proportion and airfoil sections, a wing with an

area of 200 square feet will lift twice as much at the same angle of attack and airspeed as a wing with an area of 100 square feet.

c. Airspeed. In the lift formula, lift varies as the square of velocity. Therefore, an airplane traveling at 200 miles per hour (mph), has four times as much lift as one traveling at 100 mph, so long as other factors remain constant. If airspeed is changed, then some other factor must be inversely changed to maintain the same lift. The only other factor a pilot can control is the angle of attack (para 3–8*b*). For a given airspeed and weight, there is only one angle of attack that will maintain level flight.
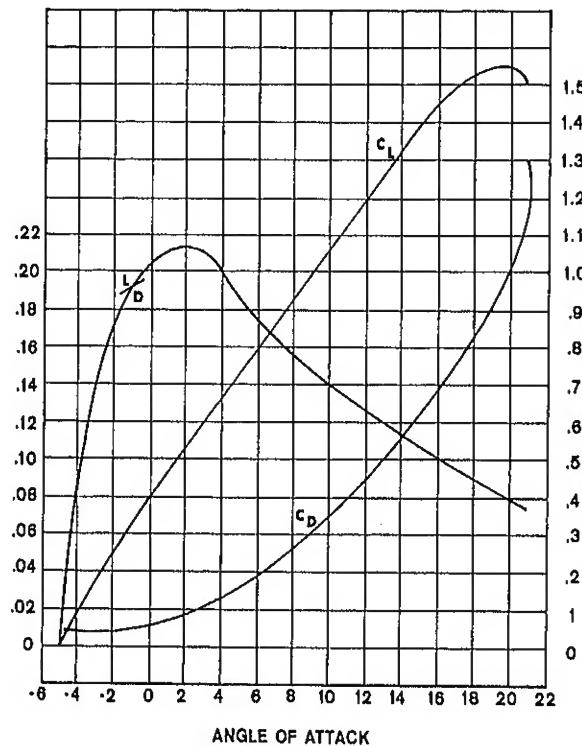
Figure 3–4. Lift-drag chart.

CHAPTER 4

FLIGHT CONTROLS AND PRINCIPLES OF FLIGHT

Section I. FLIGHT CONTROLS

4-1. General

Each flight control change affects the attitude of the aircraft and controls movement about an axis. Airplanes have three axes about which they rotate and three flight controls to effect rotation about these axes.

4-2. Operation of Controls

For desired control, the pilot should use pressures, not actual stick movements. All controls should be coordinated while flying. The following controls are discussed separately here only for clarity:

a. The *elevator* controls the rotation about the *lateral* axis. This is called *pitch*. When forward pressure is applied to the stick (A,

fig. 4-1), the elevator moves downward, causing the tail to move upward and the nose
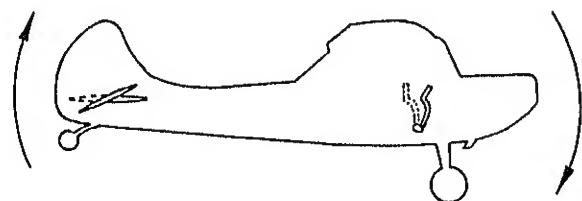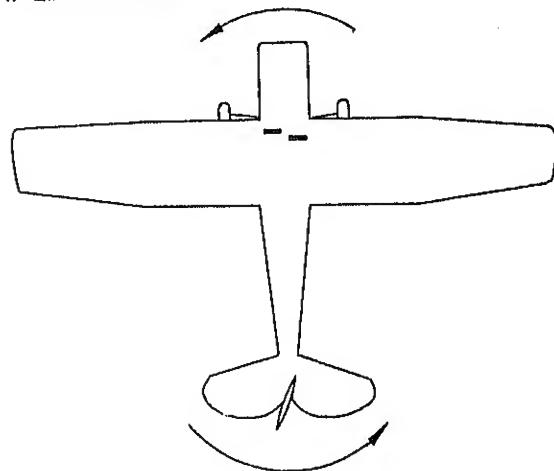
A. FORWARD STICK
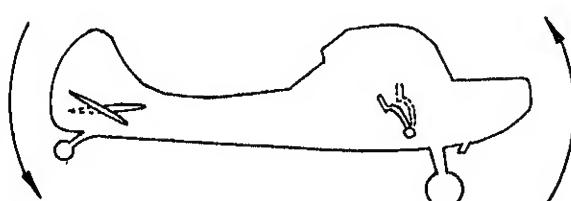
B. BACK STICK

Figure 4–1. Elevator control.

A. LEFT RUDDER

B. RIGHT RUDDER
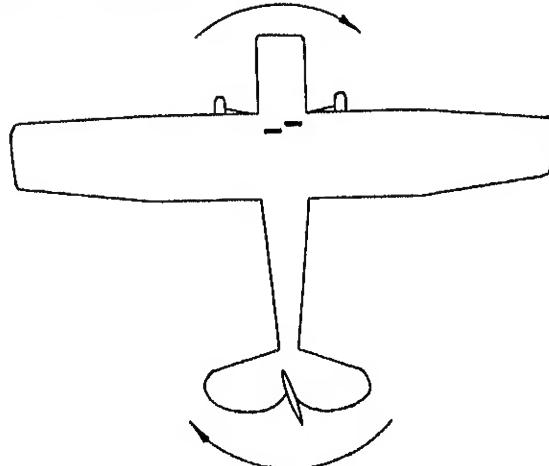
Figure 4–2. Rudder control.

A. RIGHT STICK

B. LEFT STICK
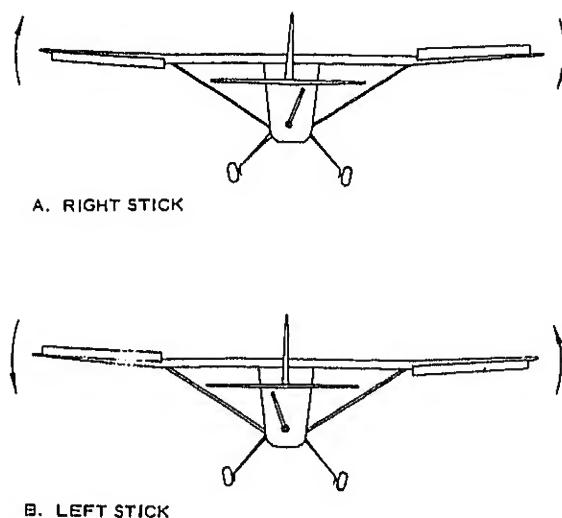
Figure 4-3. Aileron control.

downward. When back pressure is applied to the stick (B, fig. 4-1), the elevator moves upward, causing the tail to move downward and the nose upward.

b. The *rudder* controls the rotation about the *vertical* axis. This is called *yaw.* When pressure is applied to the right rudder pedal, the rudder moves to the right (B, fig. 4-2), causing the tail to move to the left and the nose to move to the right. When pressure is applied to the left rudder pedal, the rudder moves to the left (A, fig. 4-2), causing the tail to move to the right and the nose to move to the left.

c. The *ailerons* control the rotation about the *longitudinal* axis of the airplane. This is called *roll.* When right pressure is applied to the stick (A, fig. 4-3), the right aileron moves up, causing a loss of lift on that wing. At the same time, the left aileron moves down, causing an increase of lift on that wing. These aileron movements make the airplane bank to the right. When left pressure is applied to the stick (B, fig. 4-3), the left aileron moves up, causing a loss of lift on that wing; the right aileron moves down, causing an increase in lift on that wing. This makes the airplane bank to the left.

Section II. PRINCIPLES OF FLIGHT

4-3. Climbing Flight

a. The forces acting on an airplane in a climb (fig. 4-4) differ somewhat from those in straight and level flight. In the climb, lift acts perpendicularly to the flightpath, so that it does not entirely support the weight of the airplane. Weight acts in a vertical direction, and drag acts in opposition to the flightpath. Thus, thrust must overcome drag and some of the airplane weight.

b. The rate of climb (altitude gained in a given time) does not vary with the wind. However, the angle of ascent (angle between the flightpath and the horizontal) does vary with the wind for the same rate of climb. Therefore, two airplanes climbing at the same rate, one upwind and one downwind, will gain the same amount of altitude in a given time but will have different angles of ascent. Figure 4-5 shows the relative climb angle under various wind conditions.

4-4. Turning Flight

a. Turning flight is accomplished by changing lift from the vertical (A, fig. 4-6) toward the horizontal. This produces centrifugal force, which (para 3-6) tends to move an object toward the outside of a turn. The resultant of weight and centrifugal force is outward and downward. This must be overcome by lift or the airplane will lose altitude (B, fig. 4-6). Lift has a vertical and horizontal component in the turn. The resultant of these components must equal the resultant of weight and centrifugal force for a level turn. At this time, the vertical component of lift is equal to weight and the horizontal component is equal to the centrifugal force (C, fig. 4-6).

b. The resultant of weight and centrifugal force produces an increased load factor on an airplane. *Load factor* is the total load imposed on an object divided by the weight of the object, and is measured in G units. The centri-
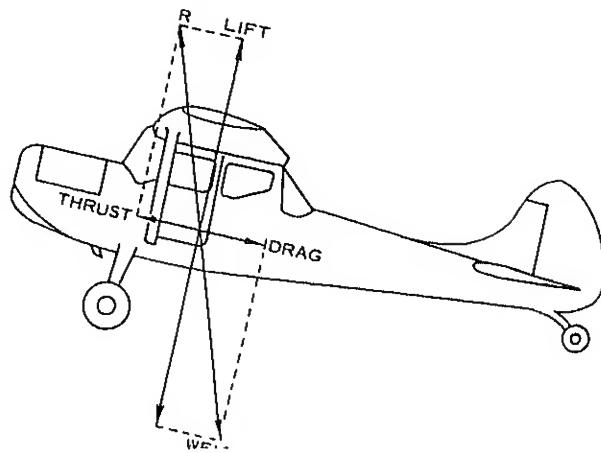
Figure 4-4. Forces in climbing flight.
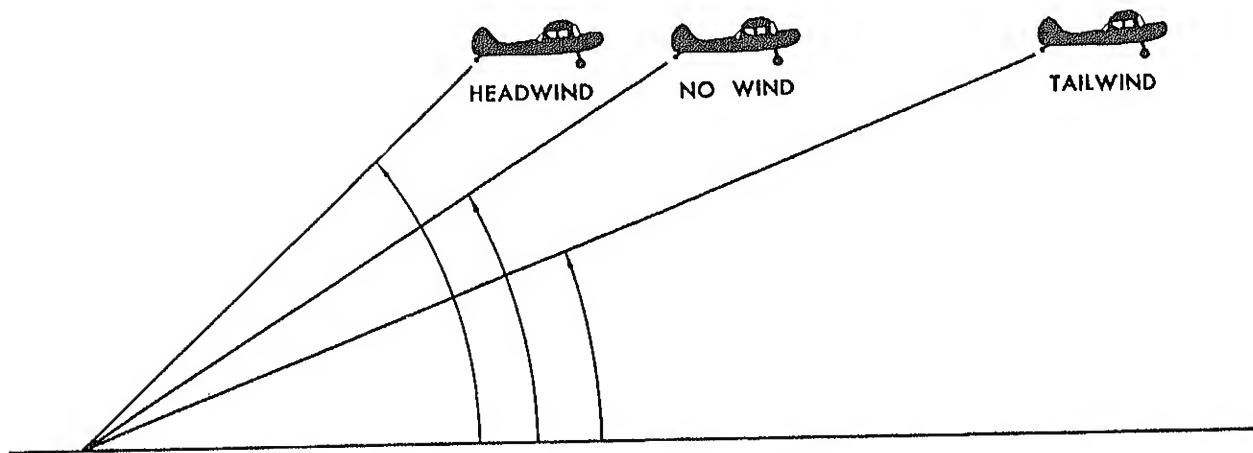

Figure 4-5. Effect of wind on a climb.
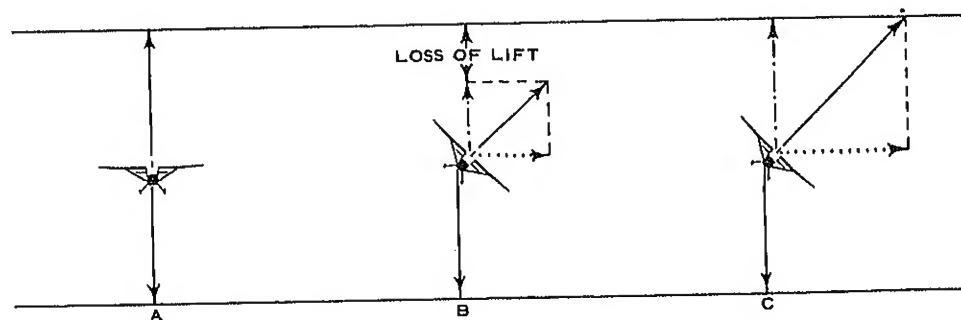
—.—.— = VERTICAL COMPONENT OF LIFT

. . . . = HORIZONTAL COMPONENT OF LIFT

LIFT AND WEIGHT ARE EQUAL ON AIRPLANE A.

VERTICAL LIFT ON B IS LESS THAN WEIGHT;

A AND B HAVE SAME ANGLE OF ATTACK.

AIRPLANE C HAS INCREASED ANGLE OF ATTACK
TO MAKE VERTICAL LIFT EQUAL WEIGHT.

Figure 4-6. Horizontal and vertical components of lift.

fugal force produced by a turn adds to the total load on the airplane, thereby increasing its load factor. The load factor is a turn is affected by angle of bank (fig. 4-7). Airspeed does not affect it because, for a given angle of bank, the rate of turn decreases with an increase in airspeed, resulting in no change of centrifugal force. In a 60° bank, the load factor for any airplane is 2 G's, regardless of airspeed. Since stalling speed varies in direct proportion to the square root of the load factor, an airplane with a normal stalling speed of 50 mph will stall at 70 mph in a 60° bank. (The square root of 2 G's is 1.41 G's. This
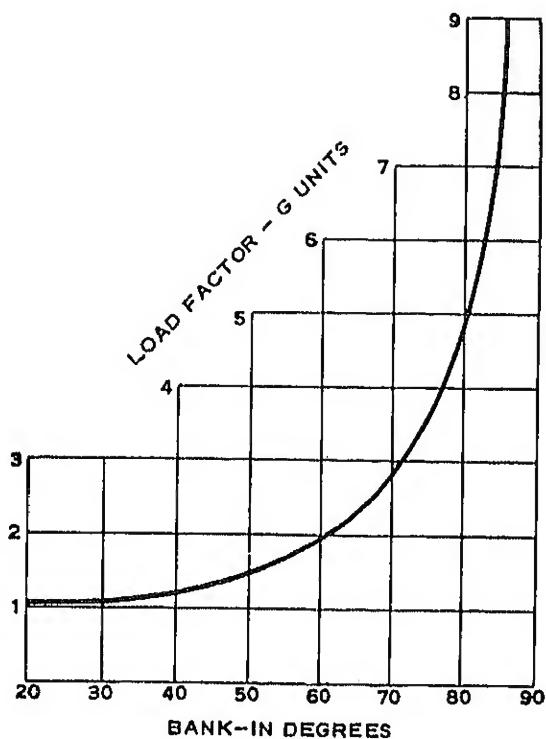
Figure 4-7. Load factors in various angles of bank.

factor multiplied by the stalling speed of 50 mph equals 70.50 mph—the new stalling speed.)

4-5. Gliding Flight

a. When the engine fails, the airplane does not drop straight down. Because the center of gravity is forward of the center of lift, the airplane will tend to nose over when power is removed. As the nose lowers, the weight com-

ponent begins to provide thrust. In doing so, it will maintain airspeed, which creates lift. Although lift is then acting perpendicular to the flightpath, it still has a vertical component. When the vertical component equals the weight component, the rate of descent and airspeed are stabilized and the airplane is in a constant glide. The thrust resultant of weight and lift then equals drag, and the vertical component of lift equals weight (fig. 4-8).

b. If the vertical lift component should become less than weight, the airplane will increase its angle of glide, causing an increase in airspeed and a resulting increase in lift. This will cause the vertical lift component to increase, and the glide will again stabilize, though at a steeper angle than normal. If stick back pressure is applied, an increase in angle of attack will result, causing a corre-
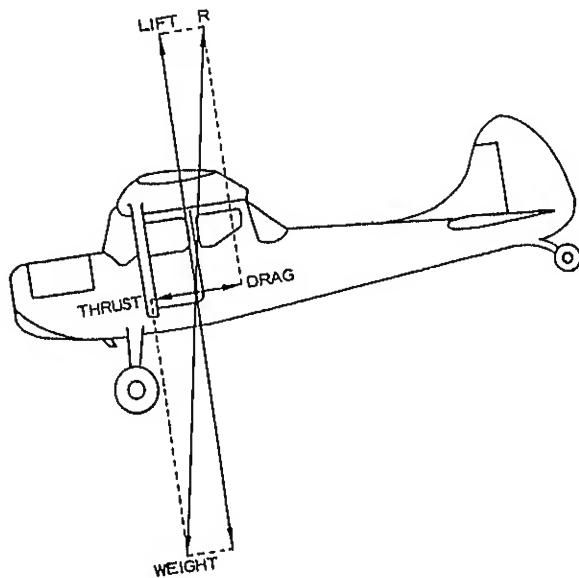
Figure 4-8. Forces in gliding flight.

sponding increase in lift and drag and a momentary decrease in angle of glide. Airspeed will begin to dissipate, causing lift to decrease until it becomes equal to weight. The glide will again stabilize, but at an angle steeper than normal because the lift-drag ratio has changed.

c. Glides can be divided into three types— *normal, slow,* and *fast.*

(1) The *normal* glide (often called "best" glide) gives the greatest forward distance for a given loss of altitude. The angle of attack and resulting airspeed which will provide the greatest lift-drag ratio is used. Airspeed must vary proportionately with weight to maintain the same angle of glide; hence, the glide will remain constant regardless of weight, provided parasite drag is not changed.

(2) A *slow* slide is one at an airspeed slower than a normal glide. The resultant angle will be steeper than that of a normal glide.

(3) A *fast* glide is one at an airspeed faster than a normal glide. The resultant angle will be steeper than that of a normal glide.

CHAPTER 5

AIRCRAFT AND PROPELLER PERFORMANCE

Section I. AIRCRAFT PERFORMANCE

5-1. Factors Affecting Performance

a. Performance characteristics of an airplane are factors such as range, endurance, rate of climb, ceiling, airspeed, and landing and takeoff speed. These factors are affected directly by the forces of lift, weight, thrust, and drag. A change of any one of the forces will cause a variation in airplane performance.

b. In the forces acting on an airplane, the most common change is its weight. An increase in weight requires a corresponding increase in lift to carry the extra weight. The increased lift requires additional thrust and/or angle of attack, which correspondingly increases drag. The net result is less speed for a given power or less range for a given speed. Operational ceiling of the airplane is lowered due to the requirements for increased lift. Rate of climb is decreased since there is less reserve power available for the climb.

c. Cruise control is the scientific operation of an airplane engine to obtain maximum efficiency commensurate with the requirements of the mission. It definitely affects the range and endurance of an airplane, and provides economy for the amount of fuel used during the flight and in overall engine wear.

5-2. Affect of Air Density on Performance

One of the most consistent and definite influences on aircraft performance is air density. Because density decreases with altitude, the air becomes thinner and causes peculiar changes in performance. At 36,000 feet, air density is one-fourth that at sea level; therefore, speed could double at this altitude and drag would remain unchanged at the normal speed. However, the decreased density also affects engine and propeller performance. To double the speed at 36,000 feet, twice the horsepower is required. Doubling the power also doubles the speed while the amount of fuel used remains the same for the same distance. But at sea level, the power requirement varies as the cube of the airspeed; to double the airspeed, eight times the power is required. The advantage of high altitude flight is thus apparent. Altitude-limiting factors of an airplane are—

a. Available Power. As air density decreases, so does available horsepower.

b. Available Lift. The aircraft reaches an altitude where the wings can no longer give sufficient lift to sustain flight with the available power.

Section II. PROPELLER PERFORMANCE

5-3. Propeller Design

The propeller is considered an airfoil because it creates a useful aerodynamic reaction when moved through the air. It receives its power from the engine, which causes the propeller to rotate and create propeller lift (commonly called *thrust*).

a. Like all airfoils, the propeller must be designed to withstand various stresses caused by the forces acting on it. Centrifugal force acts on the propeller constantly during use. This is caused by the rotation which tends to pull on the propeller from the hub toward the ends. The strength of this force varies proportionately with the speed of rotation. Lift, derived from the rotation, also produces a

force on the propeller which tends to bend it. If the bending stress on the propeller is too great, it would start "fluttering," setting up vibrations that could cause it to disintegrate.

b. At a constant rotational speed, the tip of the propeller travels at a considerably higher speed than the section nearest the hub. Therefore, to provide symmetrical loading, the propeller is twisted in design to decrease the angle of attack from hub to tip. This causes the amount of lift produced along the propeller blade to remain nearly constant from the hub to the tip.

c. When there is no forward movement of the airplane, the relative wind for the propeller is determined by the propeller's direction and speed of rotation. As the airplane moves forward, the relative wind will change, decreasing the angle of attack. All airfoils have one angle of attack which is operationally most efficient. By using a propeller on which the angle of attack can be varied as the airspeed varies, propeller efficiency can be maintained at its peak most of the time. Many types of propellers permit this. However, smaller aircraft normally use a fixed-pitch propeller—its pitch or angle of attack can be changed only by changing forward speed. Fixed-pitch propellers normally fall into two categories—*high performance* and *cruise.*

(1) The *high performance* propeller is designed to have greater propeller efficiency with little forward speed. This will permit the engine to develop nearly maximum horsepower for short, fast takeoffs, and steep climbs.

(2) The *cruise* propeller is designed to give greater propeller efficiency with more forward speed. This means a faster cruising airspeed with no more power. However, with little forward speed, the angle of attack is so great that the propeller and the engine will not turn fast enough to develop full horsepower.

d. Propellers of smaller aircraft usually are attached to the engine crankshaft. But as propeller length increases, it is not always possible to have engine and propeller rotational speeds the same. An engine must be able to attain given rpm to reach maximum horsepower. This might cause the peripheral (tip) speed of a long propeller to be too great. To compensate

for this, some propellers are geared to the engines to achieve good propeller efficiency and high engine horsepower.

e. Propellers on most multiengine airplanes can be *feathered:* the mean blade angle can be turned parallel to the direction of flight. This is an added safety factor controlled from the cockpit by the pilot.

f. Reversible-pitch propellers provide thrust in the opposite direction. They generally are used on larger multiengine airplanes. This characteristic is especially helpful to shorten the ground landing roll; it also may be used to maneuver the airplane on the ground.

g. The number of propeller blades used on an airplane is determined by the horsepower available and thrust required. Adding propeller blades is the best way to increase the surface area of the propeller. However, if too many blades are used, they follow so closely that each blade will disturb the same air; the effect is the same as a spinning tire. The result is negligible thrust.

5-4. Torque Effects

Torque reaction of a clockwise turning propeller causes a counter-clockwise rolling tendency. For straight and level flight, torque reaction is compensated for by engineering design features.

5-5. Other Left Turn (Yaw) Forces

a. Gyroscopic action (*precession*) tends to turn the airplane to the left as the tail is raised during takeoff. For a detailed explanation of gyroscopic principles, see TM 1-215.

b. The slipstream (prop wash) flows behind the propeller in a corkscrew motion. With low forward speed and high propeller speed, the corkscrew motion is tight and will strike the left side of the vertical tail surface, thereby pushing the tail to the right. As forward speed increases, the corkscrew motion elongates until its effect is slight at normal cruise.

c. Unsymmetrical loading of the propeller (*P factor*) causes an airplane to have a tendency to turn to the left. When the airplane is in a three-point attitude, the plane of propeller rotation is at an angle with the horizontal. The downward moving blade is moving for-

ward in the plane of rotation, and the upward moving blade is moving backward. As forward motion starts, this results in a greater angle of attack on the downward moving blade than on the upward moving blade. Consequently, more thrust is gained from the right side of the propeller arc until the plane of rotation becomes perpendicular to the flightpath.

CHAPTER 6

AIRPLANE CLASSIFICATION, CONSTRUCTION, AND STABILITY

Section I. CLASSIFICATION AND CONSTRUCTION

6–1. Methods of Classifying Airplanes

Airplanes may be classified by the wing, powerplant, landing gear, and purpose.

a. Wing. The number, location, and design of the wing helps classify an airplane. There may be one, two, or three wings, although most of today's airplanes are of single-wing construction. The *high-wing* airplane has the wing attached to the top of the fuselage; the *mid-wing*, perpendicularly at or near the center of the fuselage; and the *low-wing*, at the bottom of the fuselage. The wing may have the normal straight-edge design; the *sweptwing* design, where both the leading and trailing edges are at an angle to the longitudinal axis; or *delta wing* design, where the leading edge is swept back and the trailing edge forms the rear of the airplane.

b. Powerplant. An airplane may be referred to by the type of powerplant used, such as reciprocating engine or turbine engine. The reciprocating engine always uses a propeller, which may further aid in classification. A *tractor* type propeller is mounted in front of the engine; the *pusher* type propeller is located aft of the engine. The turbine engine which does not use a propeller commonly is referred to as the *jet* type; those which use a propeller usualy are called the *turboprop* type.

c. Landing Gear. There are several different types of landing gear. For landplanes, they may be either *retractable* or *fixed. Conventional* landing gear has two main wheels (one on each side of the fuselage) and a tailwheel. *Bicycle* gear has two main wheels beneath the fuselage in tandem, and usually a balance wheel under each wing. *Tricycle* gear has two main wheels, one on each side of the fuselage, and a nosewheel. Seaplanes use *floats* or the *hull*

for water operations. Amphibian airplanes are equipped for *both land and water operations.*

d. Purpose. The purpose for which an airplane is designed or used will also help classify it. This classification may be *observation, cargo, utility,* or *trainer.* Other classifications of military aircraft are not applicable to Army airplanes.

6–2. Stresses

a. Structural units of an airplane are designed to withstand various stresses while in flight and on the ground. The five types of stress are *compression, tension, bending, torsion,* and *shear.*

(1) *Compression* is the stress which tends to compress, or push together, a structural part. Sitting on a chair subjects the legs of the chair to compression stress.

(2) *Tension* is the stress pulling at opposite ends of a structural part. Movement of the controls by the pilot causes tension on the control cables.

(3) *Bending* is the stress applied to a structural unit (or beam) at other than the supporting points. It is a combination of compression and tension. When bent, one side of the beam is pushed together and the other side is stretched.

(4) *Torsion* is the stress which tends to twist a structural unit. Torsion is exerted on the propeller shaft by the engine turning the shaft and the propeller resisting the turning force.

(5) *Shear* is the stress which tends to cut an object in two by a sliding action. When two pieces of metal fastened together by rivets slide across each other in opposite directions, shear is the stress that cuts the rivets.

b. Stresses seldom act singly, but in combinations of two or more types. All five stresses may be acting on an aircraft at the same time. However, any one point cannot have more than four stresses acting on it simultaneously, since tension and compression cannot act on the same point at the same time. Any distortion of a body as a result of applied stress is called *strain.*

6–3. Dynamic Loads

In addition to the stress placed upon an airplane by normal flight, it must be designed to withstand stresses caused by acceleration and resulting centrifugal force. These additional stresses are called *dynamic loads* and are measured in terms of load factors (G units). They may be caused by various maneuvers, such as loops, snap rolls, steep turns, and abrupt pullouts from dives. If improperly done, such maneuvers may cause a greater dynamic load than the structure of the airplane can withstand, causing structural failure.

6–4. Structural Units

The principal structural units of an airplane are the fuselage, wings, control surfaces, powerplant, and landing gear. Each has a specific function and when considered collectively are called *airframe* or *aircraft structure.*

a. The *fuselage* is the main body of an airplane to which the other structural units are fastened. It will contain the crew and cargo, except external loads, and on single engine airplanes usually will contain the powerplant. The three main types of fuselage construction are *truss, monocoque,* and *semimonocoque.*

(1) The truss type is mostly used on fabric-covered airplanes. The most common truss is the Warren-type, which consists of a rigid framework made of beams, struts, and bars welded together to form triangles. Its main advantage is that members are subjected only to tension or compression stresses.

(2) A true monocoque construction consists of only the shell, with no internal bracing to help carry stresses. Consequently, it requires heavy metal for the shell and is not too desirable for military airplanes.

(3) The semimonocoque type (a modified

monocoque) is more suitable for military use. It uses rings, bulkheads, and stringers inside the shell to help give shape and carry stress. The shell (or *stressed skin*) is fastened to the internal members and can be of lightweight metal. Since stresses are divided between skin and internal bracing, vital or critical points are for the most part eliminated.

b. The *wing* provides the lifting force that makes an airplane fly and supports the weight of the airplane during flight. Its design is dependent on the size, weight, purpose, and desired speed for flight and takeoff of the airplane. There are two general types of wing construction—internally and externally braced —called *cantilever* and *semicantilever.* Each type may be covered with cloth or stressed-skin. Cloth-covered wings are lightweight and quite suitable for small, slow-speed airplanes, which usually are not subjected to severe stresses. Stressed-skin wings distribute the load over more of the wing area and, thereby, can carry more load or stress without failing. Most military airplanes are constructed with stressed-skin wings.

c. *Control surfaces* are supplementary airfoil sections which the pilot uses to control the flight of the airplane. Primary control surfaces are the *ailerons, elevators,* and *rudder;* they are constructed on the same principle as an airfoil and are covered with cloth or metal. The ailerons are attached by hinges to the outer panels of the trailing edge of the wings. Secondary control surfaces are *trim tabs, balance tabs,* and *servo tabs;* these are attached to the primary control surfaces and may be used to balance the airplane in flight or reduce the force required to move primary control surfaces. The elevators and rudder are part of the empennage, which is the entire tail group. In addition to elevators and rudder, the empennage contains the stabilizers. These normally are fixed surfaces, one vertical and one horizontal. The vertical stabilizer is used to help maintain directional stability; the rudder is attached to the stabilizer by a hinge at the trailing edge. The horizontal stabilizer may or may not be fixed. It helps to maintain longitudinal stability and, if movable, is used for trimming the airplane longitudinally. The

elevators are attached by a hinge to the trailing edge of the horizontal stabilizer.

d. The *powerplant* consist of the engine, propeller, and the necessary accessories for operation of the engine. On single-engine airplanes, the powerplant normally is mounted in the front of the fuselage. On multiengine airplanes, powerplants usually are mounted in nacelles on the wings.

e. The *landing gear* consists of wheels, shock absorbers, and possibly a retracting mechanism. Most small airplanes have fixed gear; however, larger, faster airplanes usually have retractable landing gear, which cuts down on overall drag and stress while in flight.

6–5. High Lift Devices

Only one angle of attack for a given speed will maintain a constant altitude. Flying too slowly results in excessive angle of attack and eventual stalling. The minimum (or stalling) speed for the average airplane is about $1/3$ or $2/5$ of the maximum level flight speed. A high landing speed requires a shallow gliding angle and a long runway to dissipate the excessive speed. Because of these disadvantages, the modern airplane is equipped with *high lift* devices. These devices (e.g., flaps and slots) are incorporated into the wing structure; they increase the angle of glide and allow airplanes to land at a slower airspeed. If an airplane normally is landed at the minimum flying speed for a given load, the minimum speed for flight can be found by use of the lift formula:

$$L = C_L \times \frac{D}{2} \times A \times V^2$$

To maintain horizontal flight, lift must equal weight, and the formula may be restated:

$$W = C_L \times \frac{D}{2} \times A \times V^2$$

To find the minimum speed possible, the formula may be further altered:

$$V^2 \text{ minimum} = \frac{W}{C_L \text{ maximum} \times \dfrac{D}{2} \times A}$$

$$V \text{ minimum} = \sqrt{\frac{W}{C_L \text{ maximum} \times \dfrac{D}{2} \times A}}$$

which may be simplified to:

$$V \text{ minimum} = 1.414 \sqrt{\frac{W}{C_L DA}}$$

a. The only factors that can be controlled in lowering the minimum speed are the coefficient of lift (C_L) and the area of the wing (A). Air density cannot be controlled, and it is not practical to decrease weight by dumping crew, cargo, or equipment before landing.

b. Variations in wing area, while aerodynamically sound, entail structural difficulties. The rigidity of the wing must not be impaired, the necessary additional weight of the operating mechanism must not be excessive, the strength of the wing must be maintained, and the shape of the section cannot be detrimentally affected by the variation.

c. The factor most commonly changed is coefficient of lift. It may be altered by changing the airfoil or camber while in flight. The most effective method would be to increase the upper camber of the airfoil, but this method has more structural objections than variation of the area. However, flaps can be lowered to increase the camber of the wing.

6–6. Flaps

The flap is the portion of the wing that can be turned down. This improves the lift of the wing by increasing the camber, and also acts as an airbrake, since it creates more drag. In doing so, it allows a more rapid descent at a given airspeed. Flaps have the advantages of lowering the landing speed and increasing the angle of descent.

a. *Types of Flaps.* The three common types of airplane flaps in use today are the *simple flap,* the *split flap,* and the *Fowler flap.* Though they differ in operation, their design and construction generally parallel that of the airfoil.

(1) *Simple flap.* The simple flap is a movable continuation of the trailing edge of the wing. It is similar to the aileron, except that it moves only downward, and at the same time and angle as its companion flap on the other wing. When lowered, the simple flap increases

camber of the wing and thus increases airfoil lift for a given angle of attack. However, the simple flap not only increases lift but also increases drag. This increase of drag permits a steeper glide without a corresponding increase in gliding speed.

(2) *Split flap.* The split flap consists of a flat, movable section beneath the trailing edge of the wing. When in use, it is lowered in the same manner as the simple flap, but the upper surface of the trailing edge remains in a fixed position. Its main purpose is to create drag.

(3) *Fowler flap.* The Fowler flap not only increases the effective angle of attack by increasing the camber but also increases the wing area. The flap moves both down and bakcwards, sliding out from its mounting beneath the trailing edge. Usually it is designed to form a small slot between the trailing edge of the wing and the leading edge of the flap (extended) to help decrease burbling at high angles of attack.

b. Use of Flaps. Airplanes usually are designed so that an increase in flap deflection produces a nosedown movement that rotates the nose of the airplane downward away from a stall position. Since flaps increase drag, this nosedown movement is necessary to prevent deceleration. However, some elevator control adjustment or trim may be required to stabilize the airplane at the required airspeed. Unless flight controls are used to prevent it, the opposite effect (pitchup) occurs when retracting flaps.

(1) *Flaps should never be lowered at excessive speeds,* because great stresses are produced by the sudden change in the effective angle of attack.

(2) *Flaps should never be retracted suddenly at low airspeeds,* as this causes a sudden loss of lift and increase in stalling speed. It is especially dangerous near the ground.

6-7. Types of Slot Arrangements

There are two types of slot arrangements—fixed and slat. The fixed type is built into the wing, a few inches back of the leading edge. The slat type is designed into the leading edge of the wing and, in normal flight, is a part of the wing. As airspeed decreases, it may be extended from the wing to form the slot, either manually or automatically.

6-8. Effect of Slots

Burble is caused by eddies of air over the top surface of the wing. If the eddies can be reduced, the burble point will not occur until a higher angle of attack is reached. To reduce these eddies, some wings have a slot near the leading edge of the wing. At high angles of attack, the air passes through the slot and smooths the airflow over the wing, thus delaying the stall. To make the ailerons more effective near the burble point when they are most needed, slots are commonly installed near the outer end of the wing in front of the ailerons. Two of the greatest advantages of slots are reduced stalling airspeed and prolonged aileron control during a stall.

Section II. STABILITY

6-9. Types of Stability

All airplanes possess some type of stability for safety and ease of operation. Design and construction of the airplane primarily determine its stability. There are three characteristic types of airplane stability—*positive, neutral,* or *negative.*

a. Positive stability, often referred to as stability, causes the airplane to return to its original attitude when disturbed by an outside force. It may further be divided into static and dynamic stability.

(1) Static stability tends to return an airplane to its original position when its course is disturbed.

(2) Dynamic stability is the motion of an airplane that results when it is disturbed. If the oscillation steadily decreases in amplitude, the airplane is dynamically stable; but if the oscillation steadily increases in amplitude, the airplane is dynamically unstable.

b. Neutral stability causes an airplane to maintain its attitude in flight. However, if the attitude is changed by an outside force, the

airplane will tend to maintain the new attitude until again disturbed by an outside force.

c. Negative stability (instability) tends to change an airplane from normal to abnormal flight. It constantly works against the pilot.

6-10. Stability About the Axes

Airplane stability is accomplished by controlling movement about its three axes (fig. 6-1). Certain features incorporated in the design of an airplane give it stability about its longitudinal, lateral, and vertical axes.
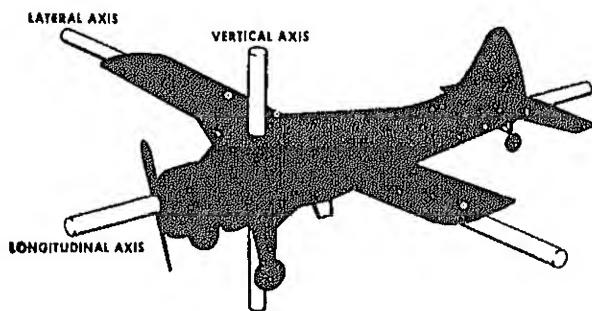

Figure 6-1. Airplane axes.

a. Longitudinal stability makes an airplane stable about its lateral axis. Without this stability, the airplane would tend to climb or dive. Longitudinal stability is achieved by designing the airplane with the center of gravity forward of the center of wing lift. This alone would cause the airplane to nose down. However, the horizontal stabilizer has a negative angle of attack which affords negative lift to the tail, thereby counterbalancing nose-heavi-

ness. If airspeed decreases, negative lift on the tail decreases, allowing it to rise and the nose to lower. This results in an increase in airspeed. As speed increases, the negative lift on the horizontal stabilizer increases, depressing the tail. If, through improper loading, the center of gravity is moved beyond the allowable limits, this stability is lost.

b. Lateral stability makes an airplane stable about its longitudinal axis. It prevents constant rolling of the airplane. Lateral stability is most commonly achieved by *dihedral* (designing the wing tips higher than the wing roots). As one wing drops, the dihedral causes the lowered wing to have more lift than the raised wing. This increase in lift tends to return the wing to its original position. Lateral stability is also achieved by *keel effect*. The fuselage of the airplane reacts to air like a keel of a ship to water. By placing the center of gravity low in the fuselage, any rolling tendency is dampened by the weight pulling downward.

c. Directional stability makes an airplane stable about its vertical axis. It tends to prevent an airplane from yawing (turning). Sweepback of the wings (the leading edge tapers back until the tip is to the rear of the root) provides some directional stability. However, the most important influence on directional stability is the slipstream action on the sides of the fuselage and the vertical stabilizer. Since a greater side area of the fuselage is behind than ahead of the center of gravity, the airplane pivots about its center of gravity and weathervanes into the relative wind.

CHAPTER 7
PRIMARY FLIGHT MANEUVERS

Section I. TAXIING

7-1. General

Flight of an Army airplane normally is preceded and followed by taxiing. Although taxiing is basic and comparatively simple, taxiing accidents are common. There is little if any excuse for them.

7-2. Use of Throttle and Flight Controls

a. Taxiing is the controlled movement of an airplane across the ground under its own power, except movement that is incident to take-off and landing. The taxiing speed is normally that of a brisk walk; however, the existing taxiing area and other conditions may alter it. Throttle, assisted sparingly and only when necessary by brakes, is used to attain and maintain desired taxiing speed. The steerable tailwheel or nosewheel, rudder, and brakes are used for directional control.

b. The amount of throttle required to start the initial roll is considerably greater than that for normal taxiing speed. Throttle should be applied slowly, and, as soon as the airplane starts to move, the brakes should be tested for proper functioning. After the taxiing roll is underway, a constant power. setting is desirable; however, if turns are made, throttle adjustments for varying wind effects may be required to maintain proper taxiing speed. S-turning may be required to improve the pilot's field of view of the taxiing area. This precautionary practice often prevents an accident. However, when in confined areas, the S-turn may be impossible and reduced speed may be the only precaution necessary.

c. Wind has a definite effect on the airplane while on the ground. It tends to retard or increase speed, as well as turn the airplane. If the pilot makes improper use of controls, a light airplane taxiing in a strong wind can be upset.

(1) If taxiing into a direct headwind (fig. 7-1), the stick should be held straight back in order to raise the elevators and exert downward force on the tail to hold it on the ground. If the wind is quartering off the nose, the stick is positioned so as to use the elevators
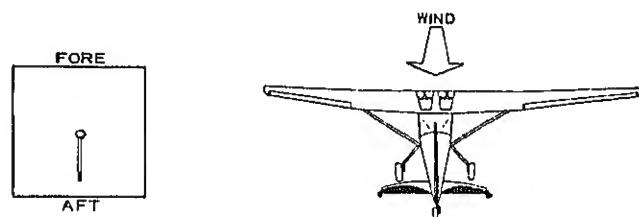

*Figure 7-1. Stick position for taxiing, headwind.*
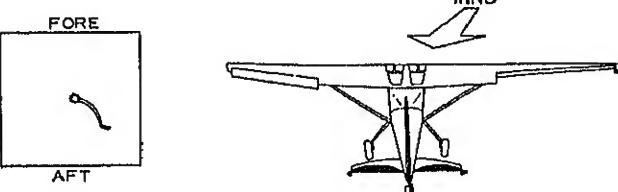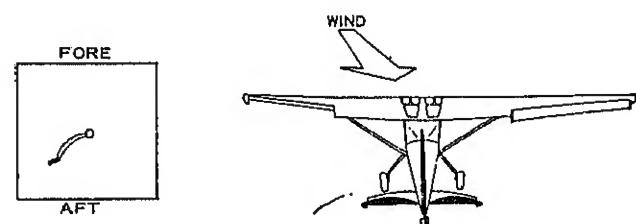
Figure 7-2. Stick positions for taxiing, quartering headwind.

and ailerons effectively to help keep the airplane upright. To do this, the stick is held back and toward the windward wing (fig. 7–2). In this position, the aileron on the windward wing moves up, spoiling lift, while simultaneously the aileron on the leeward wing lowers and creates more lift on that wing. This also creates more drag and helps counteract weathervaning tendencies. The elevator is raised to hold the tail down. In essence, then, the proper stick position for any headwind while taxiing is back and toward the windward wing.

(2) With a tailwind, the stick normally is moved forward (fig. 7–3) to lower the elevators, allowing the wind to move up and over the elevators and exert downward force on the tail. If the wind is quartering off the tail, the stick is held forward and downwind (toward the leeward wing) (fig. 7–4). In this position, the elevators produce downward force and the leeward wing aileron produces an upward force. The downward-deflected aileron also helps prevent weathervaning tendencies.
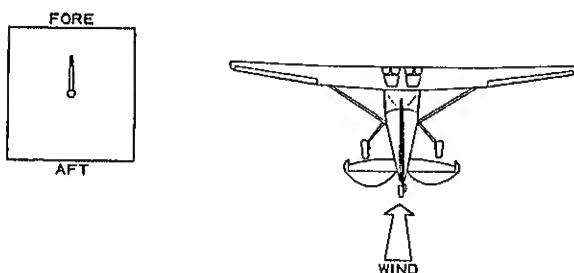

Figure 7–3. Stick position for taxiing, tailwind.

(3) Elevator position should never be held with force while taxiing in a tailwind. The propeller slipstream or taxiing speed may be strong enough to offset the tailwind; if so, the elevator has to be moved up to hold the tail down. When this condition exists, slight downward position of the elevator then normally is desirable to allow for wind gusts. Less throttle is required to taxi with a tailwind because the wind helps to move the airplane. Brakes are used as necessary to prevent excessive speed.

7–3. Taxiing Precautions

Most taxiing accidents can be eliminated by observing a few rules:

a. The aircraft must be kept under constant control.

b. When possible, S-turns should be used to afford maximum visibility of the taxiing area.

c. Speed must be commensurate with the taxiing area and pilot proficiency.

d. Sharp turns should not be attempted at excessive speeds.

e. In confined areas, wingmen or ground signalmen should be used.

f. At night, extra precautions must be taken.

g. When in doubt about the area, a thorough ground reconnaissance should be made prior to taxiing the airplane.

h. If the area appears to be too small, the airplane should be moved by hand.

i. Controls should be positioned according to wind direction and windspeed.

j. Wing-walkers should be used when windspeed is excessive or when directional control is likely to be too difficult or dangerous.
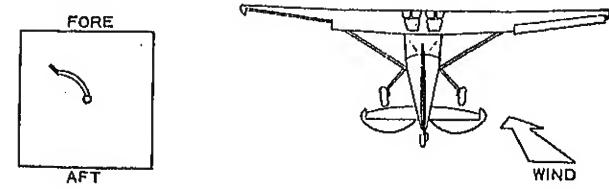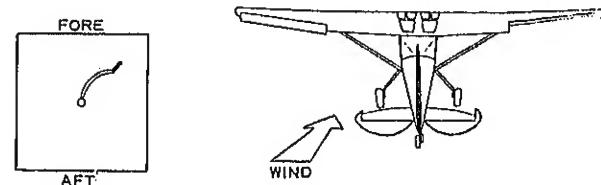

Figure 7–4. Stick positions for taxiing, quartering tailwind.

Section II. TAKEOFFS

7-4. General

Actual flight begins with the takeoff. As the throttle is advanced to start the roll down the active runway, the takeoff begins; it continues until the airplane becomes positively airborne. Mastery of the takeoff is a basic requirement of flying.

7-5. Normal Takeoff

The normal takeoff (fig. 7-5) is made directly into the wind, or as directly as the runway will allow. In this manner, the airplane becomes airborne with less ground roll and speed.

a. After clearance for takeoff is received from the tower, the airplane is taxied onto the active runway and alined down its center. The tailwheel is straightened and the throttle advanced slowly and smoothly in one continuous motion until maximum permissible power is applied. The rudder is used to counteract forces which tend to turn the airplane.

b. Once the roll is started, caution is used to prevent inadvertent application of the brakes. They are applied only as a last resort to maintain directional control. As the roll progresses, the tail may be raised by slight
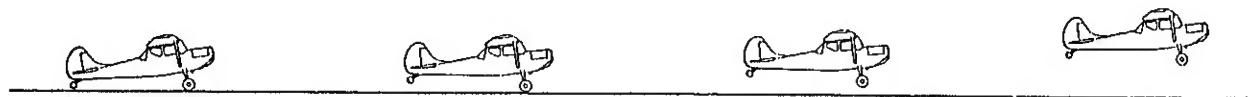

Figure 7-5. Normal takeoff.
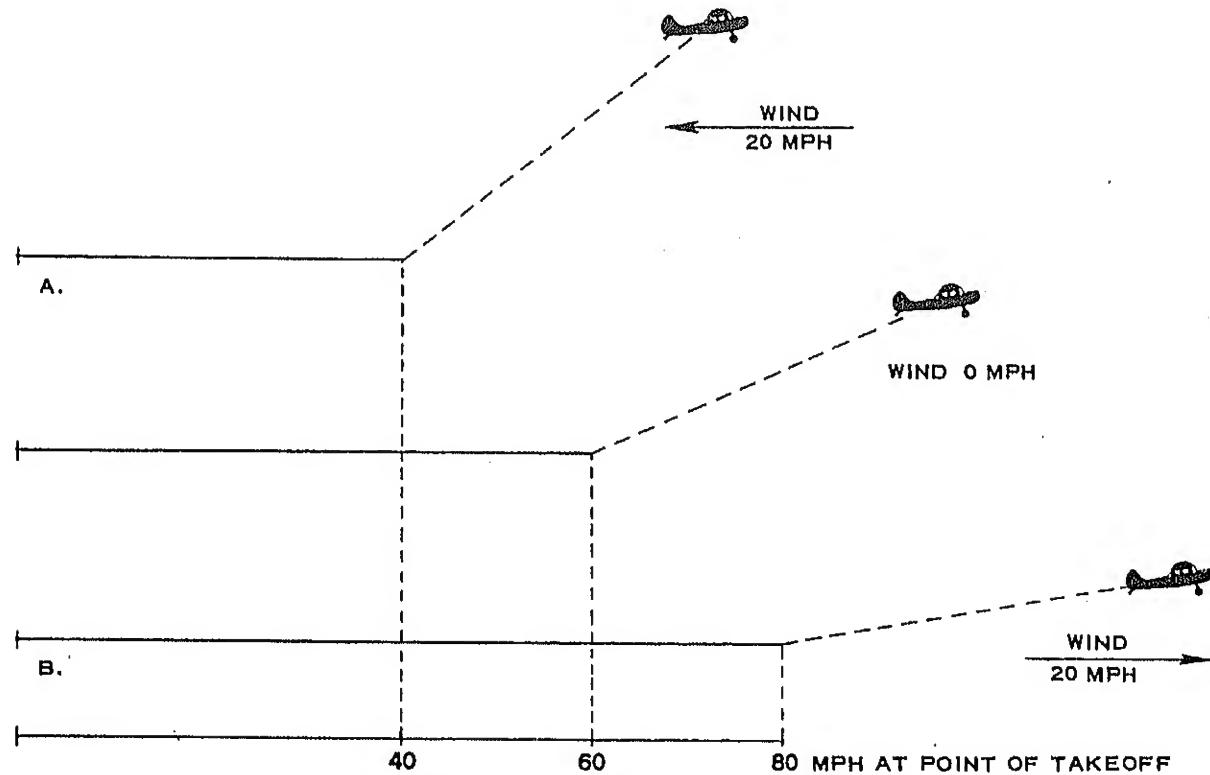
Figure 7-6. Effect of wind on takeoff.

forward stick pressure or it may be allowed to raise itself as speed increases. As takeoff speed approaches, slight back pressure is applied on the stick to prevent the tail from rising any higher. Compared to the attitude of level flight, the airplane should break ground in an attitude slightly tail low. As the airplane leaves the ground (fig. 7-5) and starts a shallow climb, it should be allowed to build up airspeed to normal climb; then normal climb attitude is assumed. Once climbing speed is obtained, power can be reduced to normal climb. The climbout should be alined with the runway.

c. Flaps are sometimes used for takeoff. They provide a shorter takeoff roll and slower takeoff airspeed. After a safe altitude and airspeed are reached, flaps should be retracted.

7-6. Effect of Wind

Takeoff depends upon the wings deriving sufficient lift to overcome the weight of the airplane. By taking off into the wind, the airplane has an airspeed equal to the headwind component before the takeoff is started. Therefore, less groundspeed is required to become airborne (A, fig. 7-6). Since groundspeed is increased above the takeoff airspeed in proportion to the value of the tailwind, a downwind takeoff requires considerably more runway (B, fig. 7-6). An airplane which will become airborne at 50-knot airspeed while taking off into a 20-knot wind will have a groundspeed of only 30 knots. But if the same airplane were to take off downwind in the same wind, the groundspeed at the time of takeoff would be 70 knots.

7-7. Effect of Field Elevation and Temperature

As altitude and temperature increase, air density decreases. This causes a corresponding decrease in lift for a given airspeed. Performance of the propeller and engine also decreases as air density decreases. Therefore, more time is required for takeoff airspeed to be attained, resulting in a longer ground roll and the need for a longer runway. Runway length requirement increases approximately 20 percent per 1,000-foot increase in altitude (fig. 7-7).
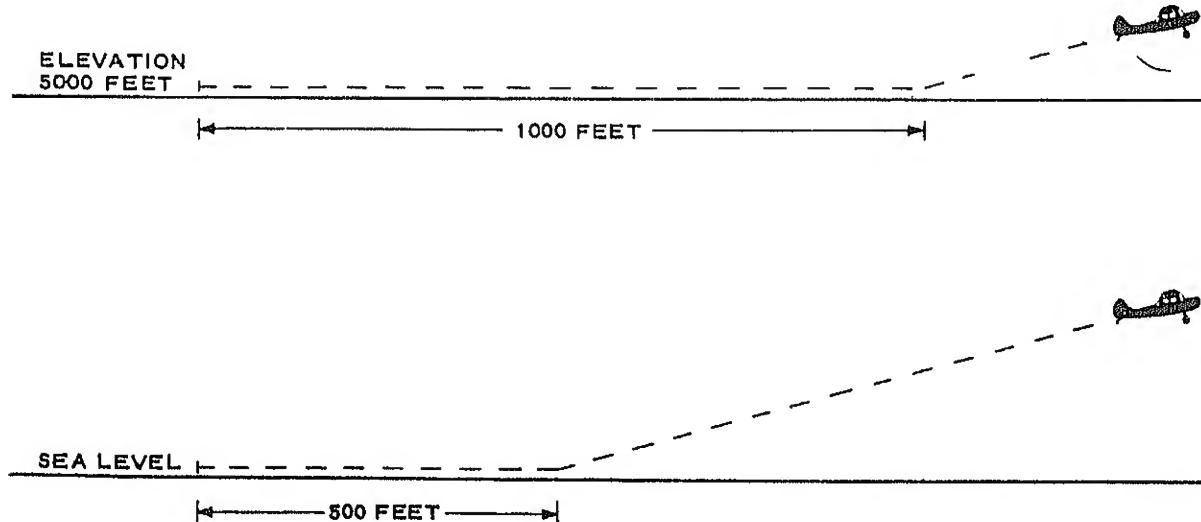

Figure 7-7. Effect of altitude on takeoff.

Section III. FUNDAMENTALS OF FLIGHT

7-8. General

There are four fundamental flight maneuvers —straight and level, climbs, glides, and turns. Mastery of these fundamental maneuvers is one of the prime requisites for pilot proficiency,

since any other flight maneuver is a combination of two or more of these.

7-9. Straight and Level

a. Perhaps the most difficult maneuver is straight and level flight since the pilot has to keep the heading and altitude constant with the wings level. This flight attitude is impossible to maintain for a long time because so many factors affect the flight attitude of an airplane. The pilot makes many small corrections to keep the airplane in straight and level flight.

b. In flight, the airplane must be kept steady with relationship to the horizon and its lateral, longitudinal, and vertical axes. These axes are three imaginary lines that are perpendicular to each other and pass through the center of gravity of the airplane. The airplane rolls about the longitudinal (nose-to-tail) axis, pitches about the lateral (side-to-side) axis, and yaws about the vertical (up-and-down) axis. The pilot uses reference points of the airplane to detect movement about each axis.

c. The longitudinal (or pitch) reference point for level flight is usually some portion of the nose, cowling, or even a bolt on the windshield. This reference point may not rest directly in line with the horizon in level flight; but if the variation from the horizon is clearly established in the pilot's mind, it will serve that purpose. A relative increase of distance between the eye and the reference point permits easier and quicker notice of changed relationship between the point and the horizon. When this reference point falls below the desired relationship, back pressure on the stick may be required to return to straight and level flight; or, if this point rises above the established relationship, forward stick pressure is required. With variations of airspeed, the pilot has to change the reference point or the relationship to fit the new level-flight attitude.

d. Lateral level flight is established by equalizing the distance between each wingtip and the horizon, and is controlled by the ailerons.

e. Checking the lateral axis for straight and level flight serves the additional purpose of verifying clearance of the area. This is an important safety habit for the pilot. Furthermore, the head motion eases pilot tension and lessens fixity of attention to a limited field of vision.

Note. Natural weight of the pilot's relaxed arm tends to hold the stick to the right of neutral, which lowers the right wing. This tendency must be guarded against. It results in decreased airplane efficiency and discomfort of passengers because the airplane is leaning (slipping).

f. Straight flight is best achieved by establishing flight relationship with a section line, road, fence line, or any ground reference point and the nose (longitudinal axis) of the airplane. The pilot uses ailerons and rudder to make corrections to maintain straight flight.

Note. A change to one of the three axes affects the others; therefore, additional control pressures are required for the other axes. However, in attempting to maintain straight and level flight, the aviator must not constantly alter flight controls. An airplane will roll and pitch with air turbulance, but if practicable, it should be allowed to level itself by inherent design stability. Extreme pilot fatigue results from constant control corrections.

7-10. Climbs

Climbs are used for ascent to a higher altitude. The two types of climb an Army aviator will use are *normal* and *maximum*, with maximum climb limited to short durations only.

a. The *normal climb* is made at an angle, airspeed, and power which will give a desirable lift-drag ratio and adequate speed for engine cooling. The power setting is above normal cruise but usually less than full throttle.

b. Normal climb attitude is entered from straight and level flight by the pilot applying back pressure to to rise, airspeed l should be slow climbing powe. pilot maintains erence points until flight exp

Note. Flight co at the slower clim pressures more sl cockpit decreases noise increases.

c. Increased sult in a left

compensate, pressure on the right rudder pedal is required throughout the climb. If rudder trim is available by cockpit control, it should be used to relieve pedal pressure. If available, elevator trim should also be used to relieve stick pressure during the climb.

d. When the desired altitude is reached, the pilot returns the airplane to level flight at normal cruise power and airspeed. This is best accomplished by starting to lower the nose of the airplane as the desired altitude is approached and by maintaining climb power. When altitude and cruising airspeed are reached, the level-off is completed by reducing power to normal cruise. The pilot then retrims the airplane for straight and level flight at normal cruise.

(1) As airspeed increases during the level-off, less right rudder or trim is required.

(2) After attaining straight and level flight at normal cruise airspeed, power should be reduced and the airplane retrimmed.

7–11. Glides

The glide is used to descend to a lower altitude. The *normal glide* is a glide at an angle and airspeed permitting the greatest forward distance with a given loss of altitude.

a. To enter the glide from a straight and level flight, the pilot closes the throttle in a smooth, slow motion. He holds the airplane attitude constant until the airspeed dissipates to normal glide airspeed for the particular airplane, at which time he lowers the nose to maintain that airspeed. With reduced power and airspeed, he changes control pressures on both stick and rudder pedals to maintain glide attitude. Without power, the airplane tends to turn to the right, and the left rudder pedal has to be used to counteract this tendency. As airspeed decreases, back pressure must be applied to the stick to keep the nose in level attitude. When gliding airspeed is reached, the pilot reduces back pressure to lower the nose and to maintain gliding airspeed. Subsequent control pressures are applied only as necessary to maintain the gliding attitude. If available, trim is used to relieve pilot control pressures.

b. As in the climb, initial glide training requires reference points to maintain correct glide attitude until the ability to sense and feel the proper speed and attitude is developed. The marked absence of engine noise permits keener aural perception of changes in airspeed and helps the pilot to make corrections.

c. The level-off from a normal glide should begin about 50 feet prior to reaching the desired altitude. At this time, the pilot increases power slowly and smoothly. Airspeed starts to increase and reaches normal cruise with the pilot holding to normal cruise power and straight and level flight. As power increases, the pilot adjusts rudder or trim to maintain heading. After the airplane has stabilized in straight and level flight attitude, the pilot retrims the airplane to relieve control pressures.

d. Wind affects a glide (fig. 7–8) by varying ground track and distance covered. In a headwind, the glidepath will be steeper if the airspeed remains unchanged because the effective headwind will reduce the groundspeed of the airplane by the amount of that component. An airplane gliding at 60 knots into a headwind of 60 knots will have a groundspeed of zero and will make a vertical descent. By the same analysis, the same aircraft gliding with a 60-knot tailwind will have a groundspeed of approximately 120 knots and a proportionately shallower glidepath.

## 7–12. Turns

Turns are used to change the direction of the

HEADWIND   NO WIND   TAILWIND
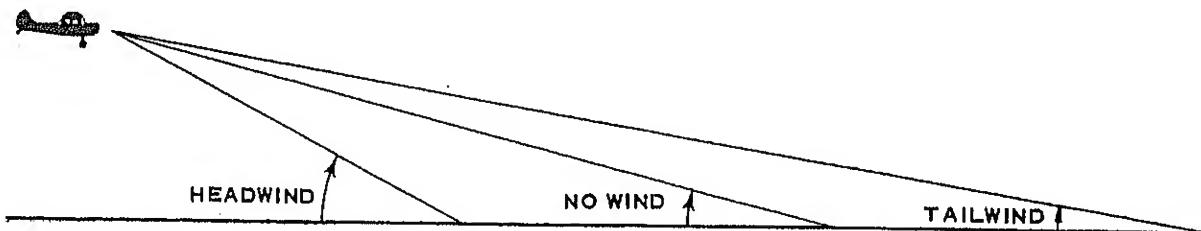
Figure 7–8. Effect of wind on a glide.
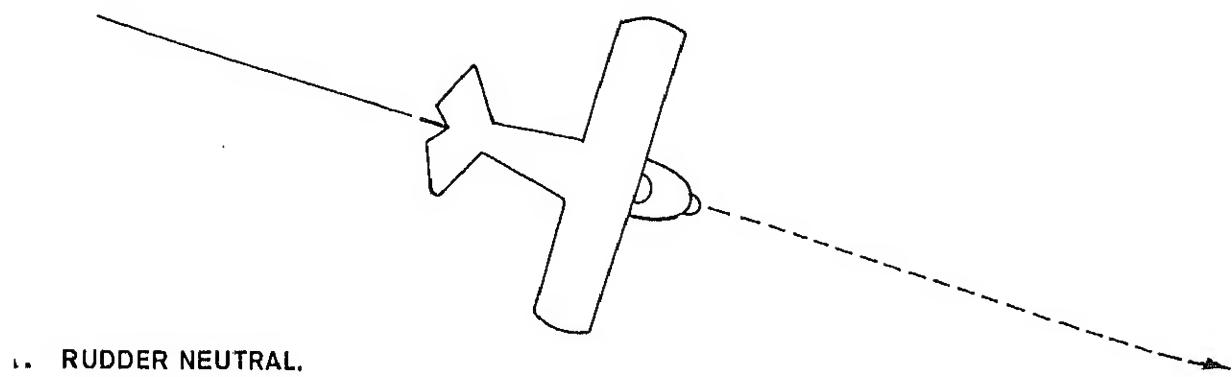
i. RUDDER NEUTRAL.
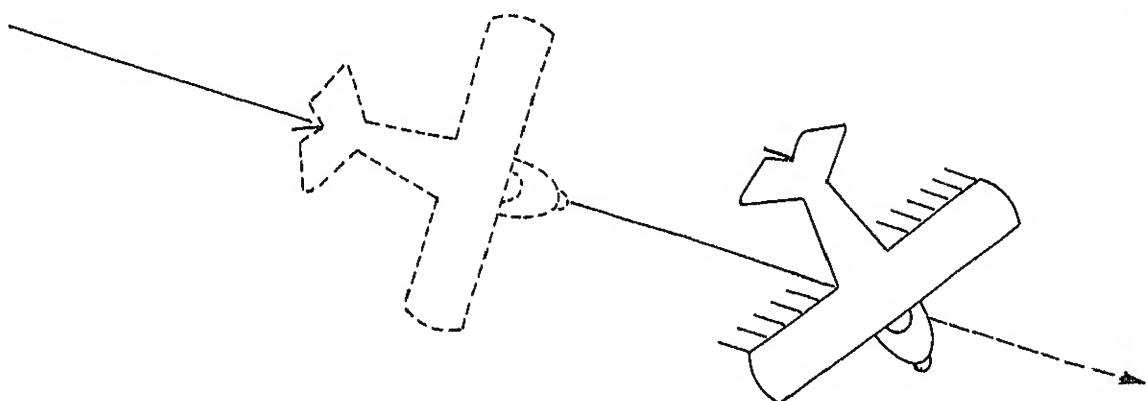
i. RUDDER INTO THE TURN, OR EXCESS TURN FOR DEGREE OF BANK—SKIDDING RESULTS.
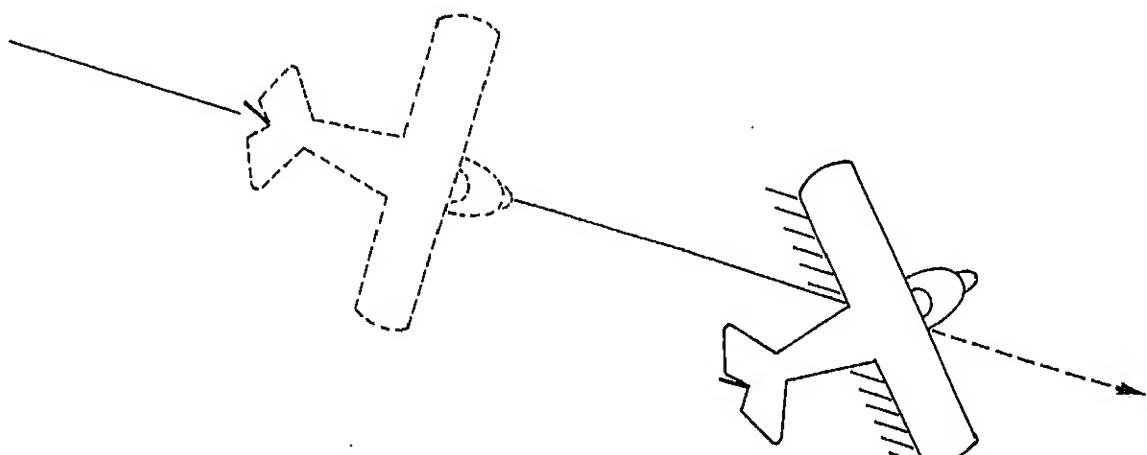
i. OPPOSITE RUDDER, OR INSUFFICIENT TURN FOR BANK ENTERED—SLIPPING RESULTS.

★*Figure 7-9. Effect of rudder in turns.*

flightpath. Their three general classifications are *shallow, medium,* and *steep.*

a. Turns are made by inclining the airplane's lateral axis toward the horizon. By moving the ailerons, a difference of lift on each wing causes the airplane to bank.

b. Since drag increases with lift and the ailerons cause a difference in lift, an airplane being banked in one direction tends to yaw in the opposite direction. The use of slight stick pressures will reduce the yawing tendency, but will considerably increase the time required to establish the bank.

★c. Rudder is used to prevent yaw when entering or recovering from a bank; however, it is not used to turn the airplane. *For example,* if the stick is moved to the right, the pilot uses right rudder until the bank is established. The rudder pressure is then released and the rudder allowed to streamline (A, fig. 7-9). If bottom (inside) rudder pressure is held during the turn, the airplane will skid (B, fig. 7-9). If top (outside) rudder pressure is applied, the airplane will slip (C, fig. 7-9).

d. When a turn is started, the pilot increases stick back pressure to maintain level flight. This increases the angle of attack and results in more lift, which compensates for the centrifugal force of the turn (para 4-4). The amount of back pressure on the stick is in proportion to the steepness of the bank.

e. An airplane is correctly banked and subsequently turned by coordinated use of rudder, ailerons, and elevator. The relative use of these controls is determined by the characteristics of the particular airplane and the airspeed at which the maneuver is executed. After the airplane has been banked for a turn, the angle of bank should be held constant without skidding of slipping. This requires some adjustment of aileron, rudder, and elevator pressures, depending upon the characteristics of the airplane and its speed. General rules cannot be set for determining, in advance, the exact amount of control pressures for a specified airplane; the pressures must be learned from actual practice.

f. The stalling speed of an airplane is increased in a turn because of the increase of aerodynamic load from centrifugal force. The increase of stalling speed is proportional to the square root of the load factor. Therefore, an airplane with a normal stalling speed of 60 knots will stall at 120 knots with a load factor of 4 G's (para 4-4b).

g. Climbing turns generally are made with a shallow bank. With the shallow angle, the bank is not steep enough to cause the resultant of lift to drop appreciably. However, since airspeed is less than at normal cruise and power greater, torque tends to turn the airplane to the left. In airplanes without trim control, entry in a left climbing turn does not always require left rudder pedal; instead, a slight relaxation of pressure on the right rudder pedal will prevent skidding. In entering a right climbing turn, the pilot must increase rudder pressure beyond that of a straight climb.

h. Gliding turns generally should be at a medium bank. However, if the situation requires a steeper bank, the aviator must remember that stalling speed increases as the bank increases, and that the reduced speed of the glide leads to an earlier stall with less bank than at normal cruising speed.

Section IV. CONFIDENCE MANEUVERS

7-13. General

Most airplanes must be forced into a dangerous attitude, and even then, if permitted to do so, they usually will right themselves to normal flight attitude. Through practice of confidence maneuvers, the pilot gains respect for airplane stability and maneuverability.

7-14. Slow Flight

Slow flight serves two purposes. It teaches the beginning student that the airplane will fly with sufficient control at reduced airspeeds. For the experienced aviator, it serves as a review and coordination exercise for power approach technique.

a. Slow flight may be at any airspeed between normal cruise and stalling, but is usually flown about 10 knots above stalling airspeed. Power is used as necessary to control altitude.

b. Slow flight is entered by reducing power and letting the airspeed dissipate. Altitude is kept constant by increasing stick back pressure as airspeed dissipates. When the desired airspeed is reached, required power is added to control altitude. Turns can then be executed, but the angle of bank should be very limited due to reduced airspeed.

7–15. Stalls

An airplane will stall only when an excessive angle of attack is reached. The stall (fig. 7–10) may occur at reduced airspeed or at an airspeed above normal cruise following an abrupt change of attitude. When the stall occurs, the aviator must be able to recognize it as such and take proper corrective action. Practice stalls are, therefore, part of confidence maneuvers.

a. An airplane will stall at the same angle of attack without regard to pitch attitude (A, B, and C, fig. 7–10). In a power-off stall (A, fig. 7–10) the throttle is closed and a normal glide is entered. The nose is raised approximately to the three-point attitude, which is maintained until the stall occurs. At this time, the nose will drop below level flight attitude; as flying speed is regained, the airplane will tend to assume a normal glide attitude. If improperly rigged or if the wings are not level as the stall occurs, the airplane may fall off on one wing; that is, instead of the nose falling straight through, it will start turning toward one wing. As flying speed is regained, however, the airplane may tend to correct its attitude.

b. For the normal power-on stall (B, fig. 7–10), power and resultant thrust require greater pitch attitude. Normally, a given pitch attitude is maintained until the stall occurs. As airspeed starts dissipating, the pilot compensates left turn effect with right rudder. As stall occurs and the nose starts dropping, with airspeed increasing, he releases right rudder pressure.

c. Initially, stall recovery should be effected

A. POWER-OFF STALL

B. POWER-ON STALL

C. HIGH-SPEED STALL
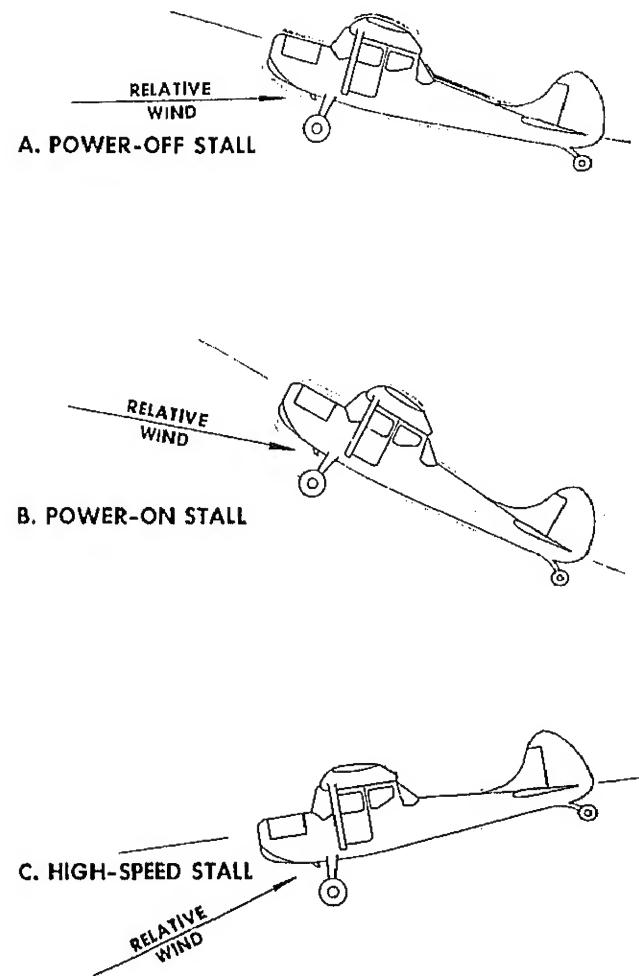
Figure 7–10. Relative stall attitudes.

in a positive manner by lowering the nose and applying power to regain flying speed, then easing back on the stick and reducing throttle to attain straight and level flight at cruising power. A constant heading is maintained throughout the recovery. To reduce the angle of attack to an angle less than the stalling angle, which varies with the type of airplane, the pilot either lowers the nose, adds power, or both.

d. As proficiency in stall recognition and recovery develops, the pilot can complete the recovery with less loss of altitude. He should practice this until recovery can be made at the moment the stall occurs. As the airplane stalls, he applies full throttle to increase the thrust, and thereby helps break the stall. However,

since the pilot has minimum control and the airplane may enter unusual attitudes that are dangerous to the inexperienced aviator, this type of recovery should not be practiced until the pilot has developed some proficiency.

e. The airplane can stall in both gliding and climbing turns and these should therefore be practiced. Stall recovery is accomplished by lowering the nose to lessen the angle of attack. Then, the wings are leveled and the nose pulled back to level flight attitude. Power may be used to help execute recovery.

7-16. Spins

The ability to recover from a spin is essential to safe flying and bolsters pilot morale and confidence. A high degree of proficiency is required to avoid an accidental or unintentional spin. Generally, airplanes are designed to resist spinning. Yet, at minimum airspeed, spinning is possible by mishandling of the controls. It may occur so easily and smoothly that the inexperienced aviator detects the change only after spin entry. Little or no warning may precede this type of spin.

a. Normally, the intentional spin is a maneuver in which the airplane descends in a helical path while in a stalled condition, rotating about its vertical and longitudinal axes. It may be entered from either a power-on or power-off stall.

b. When the spin is entered, proper pilot control to keep the airplane spinning consists of full rudder, full back stick, and neutral ailerons. Rudder is held toward the inside of the spin. If either rudder or elevator pressure is relaxed, the airplane normally tends to fly out of the spin.

c. Recovery from the spin is achieved by stopping the rotation and breaking the stall. Rotation is stopped by applying positive, opposite rudder. In most airplanes, the stall is broken by releasing back pressure, at which time the rudder is neutralized to avoid a skid-

ding recovery. By slight back pressure on the stick, the airplane is eased out of the resulting dive and returned to straight and level flight. Power is added as airspeed returns to normal cruise. If the recovery from the dive is too abrupt, a secondary stall may occur, with recovery from it resulting in a further increase of airspeed. It is also possible to exceed maximum safe (G) load factor if the pullout from the dive is too abrupt.

7-17. Elementary Forced Landing

A forced landing may be caused by a partial loss of power or complete engine failure, malfunction of one or more controls, collision with an object, depletion of fuel supply, bad weather, disorientation, and so forth. Being constantly alert for such conditions, an aviator will be better able to meet the requirements presented by a forced landing. Through practice of simulated forced landings, he learns to react to the situation quickly and with confidence.

a. Since glides usually are performed with little or no power, forced landings require considerable proficiency. Each forced landing, simulated or actual, has specific problems that may never again be duplicated; therefore, each requires thorough planning. The aviator must plan his landing pattern while retaining control of the airplane; thereafter, except to avoid certain disaster, he must follow the selected plan.

b. After power is reduced for a simulated forced landing, the pilot glides the airplane from the initial altitude until he can determine that the maneuver will or will not succeed. During the glide, he performs the cockpit procedure necessary to accomplish an airstart while selecting the landing area and planning the approach. He turn onto the final approach at a safe altitude. After determining the success of the simulated maneuver, he adds power and the airplane climbs to a higher altitude.

Section V. COORDINATION EXERCISES

18. General

dination exercises vary in degree of diffi- ; but together they develop and maintain

proficiency in the coordinated use of flight controls. They should be practiced throughout an aviator's career.

7-19. Banks Without Turns

a. The first of two elementary coordination exercises is that of a series of banks without letting the airplane turn, sometimes referred to as the "Dutch Roll" or control timing. Although the airplane does *slip* during the maneuver, the aviator develops a perceptual motor skill—the ability to perceive flight characteristics or faults and to respond instinctively with corrective action.

b. To perform this maneuver, a constant heading is maintained while the airplane is rolled back and forth from right to left banks without pause at the wings-level position. Altitude is kept constant. The degree of bank may be increased progressively with skill in performance of the maneuver, or a specified degree of bank may be used. Combining this maneuver with climbs and glides further develops pilot control feel, timing, and alertness.

7-20. Banks With Turns

a. The second elementary coordination exercise consists of banks with turns. The bank is shallow at first, with the angle increased as proficiency develops. The airplane is allowed to turn while the pilot maintains continuous coordinated flight.

b. A reference line on the ground, normally a straight road or fence row, is chosen and the airplane flown above and in alinement with this ground line. The pilot starts the first turn in either direction and allows it to continue until the angle is approximately 45° of turn from the original heading, at which time a turn in the opposite direction is started and continued for 90° (45° from the original heading in the opposite direction).

c. The entry of the turn, or roll-in, should be smooth and steady until the desired degree of bank is attained. The change from one bank to one in the opposite direction is continuous, without pause at the wings-level position. The new turn is continued for 90° (45° from original heading in the opposite direction). Altitude should be held constant, and all turns should be fully coordinated.

Section VI. PRIMARY GROUND TRACK MANEUVERS

7-21. General

Much Army aviation flying is at low altitudes and requires frequent and often prolonged observations beyond the confines of the airplane cockpit. Therefore, the aviator must develop perceptual motor skills to such a degree that he reacts automatically and safely to flight requirements while keeping most of his attention on mission requirements.

7-22. Rectangular Course

The rectangular course is an elementary ground track maneuver, but even an experienced aviator may fail to fly a good rectangular course if he does not closely follow well-planned procedures.

a. An area approximately ½-mile square, or as close to this measure as terrain permits, with straight sides and well-defined corners is selected for the exercise. Usually the airplane is flown around this area at the established traffic pattern altitude, and away from and parallel to the sides of this area (fig. 7-11) at a distance equal to the turn radius of the airplane in a medium bank. When flying crosswind, the airplane is crabbed as necessary to maintain a ground track parallel to the area sides. Each turn is started when the corner is reached, and executed so as to roll out of the turn when the corner is completed at the prescribed distance from the next side to be flown. The arc described over the ground during the turn should be equidistant from the corner at all times; together, all four turns should form a circle (fig. 7-12). The bank varies on each turn, as necessary, to compensate for wind and maintain a constant-radius turn.

b. While flying the rectangular course, attention must be divided between outside alinements and control of the airplane. Ground track should be parallel with the area sides and with altitude held constant. Roll-in and rollout of turns must be properly timed, and bank must be correctly varied to give a constant-radius turn regardless of wind direction. An aviator who thoroughly understands and

is able to fly a good rectangular course has the foundation basis for flying the traffic pattern (sec VII).
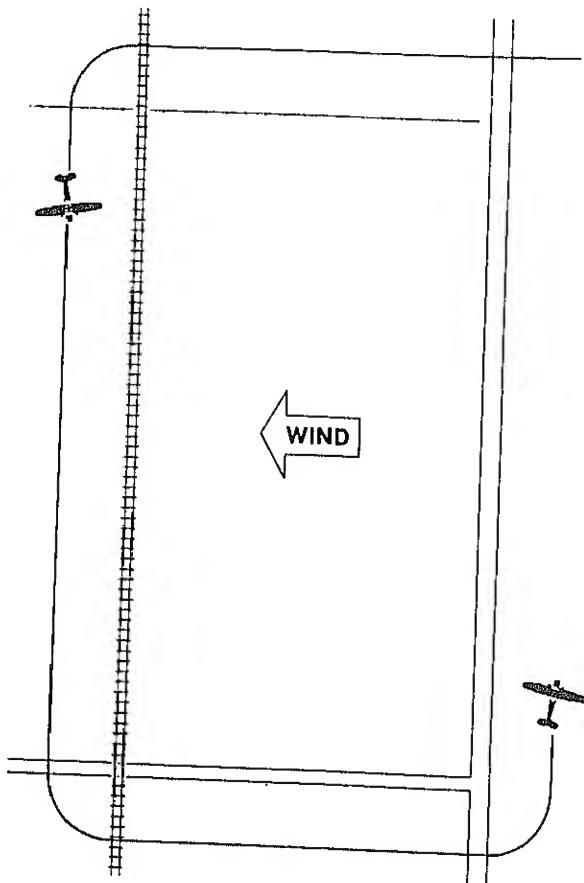

Figure 7-11. Rectangular course.

7-23. S-Turns Across A Road

Because wind affects ground track, proper timing of entry and exit of turns is a definite requirement for safe flying. Pilot perceptions during turns near the ground are different from those at higher altitude and can cause control errors which lead to the accidental spin. Therefore, benefits gained from the exercise of S-turning across a road are a vital part of pilot training.

a. For the exercise, a straight road (or fence line) is selected which runs *perpendicular* to the wind, or as close to perpendicular as possible. The airplane initially is flown either into the wind or downwind to cross the road at right angles. As the road is crossed,
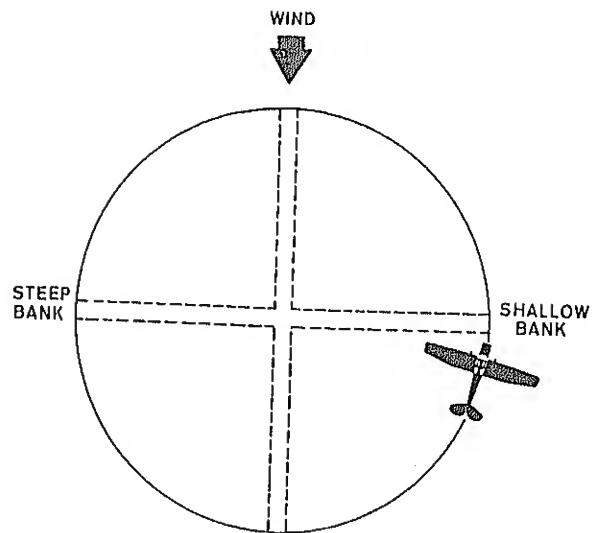

Figure 7-12. Wind circle.

the pilot starts a turn in either direction and continues it through 180°. The turn is timed so that the airplane crosses the road perpendicularly as the wing reaches level attitude during rollout. Then the pilot immediately starts a turn in the opposite direction and times it as in the first turn. The complete turn should make a semicircular ground pattern (fig. 7-13). The speed of the airplane will determine the radius of the circle flown. Under no-wind conditions, a medium bank angle should provide the correct distance. Since bank can be controlled easier than groundspeed, it is necessary to vary the amount of bank in order to fly a semicircular ground track on each side of the road.
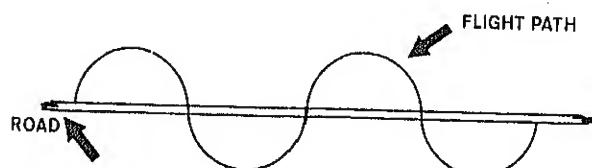

Figure 7-13. S-turns across a road.
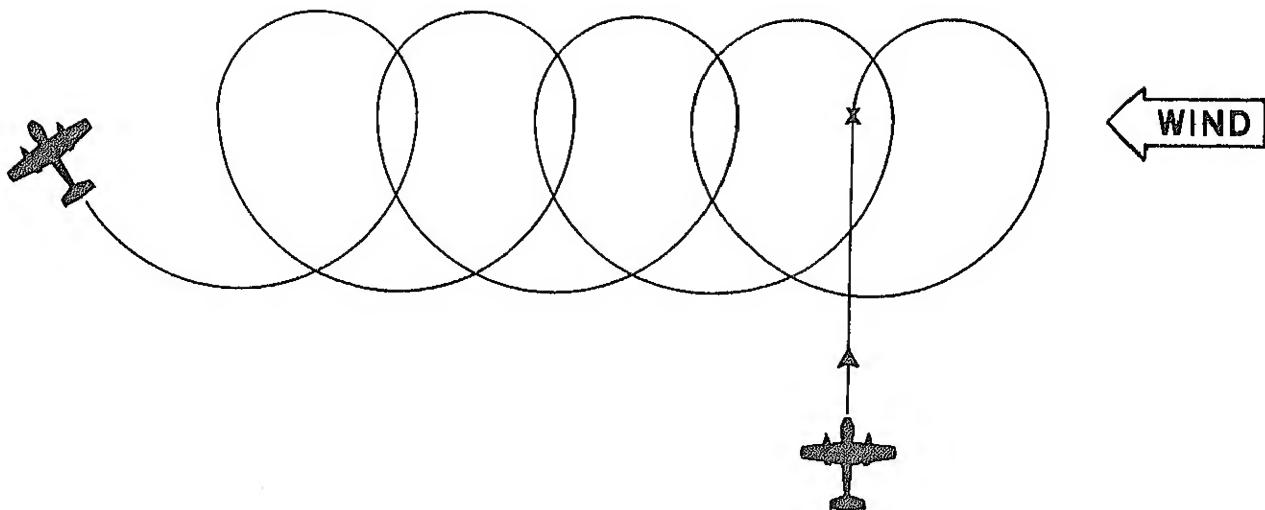
Figure 7-14. Effect of wind on a constant rate turn.

b. The greatest groundspeed is developed flying downwind and will require the steepest bank in the turn. Flying upwind, the opposite is true: the shallowest bank will be required in the turn.

c. Analysis of the maneuver through a complete turn will reveal that the bank begins slowly and is gradually increased throughout the initial 180° of turn. This is because groundspeed is constantly increasing. The rollout is quite fast; and, without hesitation, a new bank in the opposite direction is started with a fast roll-in to get the bank established. As this turn progresses, the amount of bank should gradually decrease since groundspeed decreases throughout the second 180° of turn. Altitude remains constant during the entire maneuver.

7-24. Elementary 8's

The elementary 8 describes a path over the ground resembling the written number. Without wind, the maneuver is simple; with wind, the maneuver offers important training for the aviator developing perceptual motor skills and good subconscious flying habits. Figure 7-14 shows how wind affects the ground track at a constant rate of turn. There are many types of figure 8's, progressing from elementary to ad-

vanced maneuvering skills. Only one type will be described here—the crossroad 8.

a. For this maneuver, select a crossroad or an intersection with one of the roads being as nearly perpendicular to the wind as possible. (Roads offer ready identification of flight position during the maneuver.) The figure 8 is flown so that two circles are tangent at the intersection and bisected by the road perpendicular to the wind (fig. 7-15).

b. The maneuver normally is entered by flying into the wind over the intersection at the altitude prescribed for ground track maneuvers. As the intersection is crossed, a turn is started in either direction, with the bank varied so as to complete a circle as the intersection is again crossed. At this time, a second turn is started in opposite direction to the first to accomplish a circle on the opposite side of the road intersection. The radius of the circle flown will be determined by the speed of the airplane. Under no-wind conditions, a medium bank angle should provide the correct distance.

★*c.* The maneuver requires great division of pilot attention between flying and ground track since each turn involves 360° and a constantly changing bank.

WIND
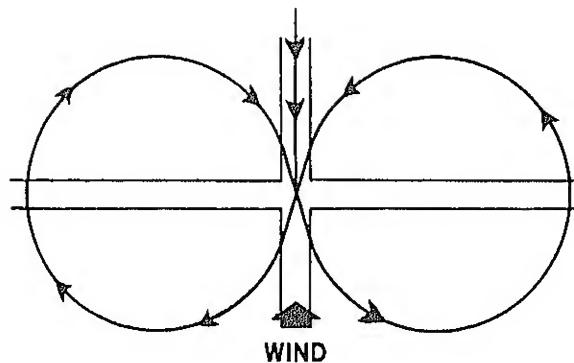
★*Figure 7-15. Crossroad 8.*

Section VII. TRAFFIC PATTERN

7-25. General

The traffic pattern is a method of expediting the flow of air traffic about an airfield with safety and regularity. It requires division of attention by the pilot between watching for other aircraft, attention to tower signals, and airplane control.

7-26. Description

꿈̄ traffic pattern is a designated flightpath
s and takeoffs at an airfield. Nor-
flightpath is of rectangular shape,
꿈꿈꿈y forming one side, with all
he left in forming the other
'-16). Each side is referred to
:, crosswind, downwind, base,
he latter occurs after the last

turn before landing and is called *final approach.* The normal pattern is flown 1,000 feet above the terrain. The first turn after takeoff may be started before reaching 1,000 feet, but should not be less than 500 feet or until the field boundary is crossed, whichever comes last. When other traffic is in the pattern, the takeoff leg may be flown straight to acquire adequate spacing between airplanes. (The climb is continued to the designated altitude, which is then maintained.) The turn from crosswind to downwind should be so executed as to place the airplane at the proper distance from the runway. Depending upon the airplane and the traffic pattern altitude, proximity to the runway may range from 1,000 to 5,000 feet, with 2,000 feet usually adequate.
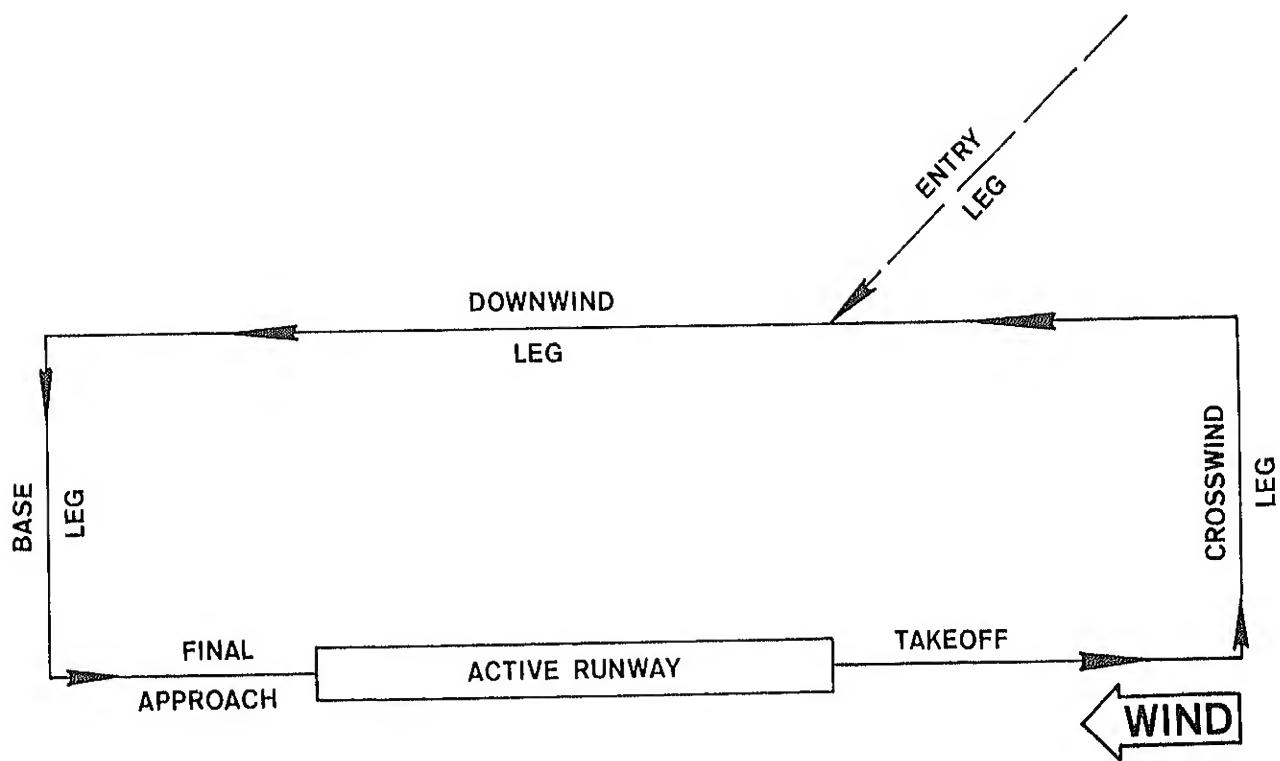
Figure 7–16. Traffic pattern.

7-27. Use

Entry into a traffic pattern is made by flying toward the field at a 45° angle to the downwind leg. This entry reveals the pilot's intentions and affords excellent pilot visibility for checking the area for other aircraft in the pattern. As the downwind leg is reached just short of the field, the airplane is turned 45° to fly the downwind leg (fig. 7-16).

7-28. Approach

The 180° side approach normally is used. It involves two turns of 90° each. On the downwind leg of the traffic pattern, at a point opposite the point of intended landing, the pilot reduces power and establishes a descent. He should start a turn to position the base leg to a safe altitude for final turn prior to crossing the field boundary. He times the turn onto final approach to roll out in alinement with

the runway, maintaining normal approach speed throughout the approach until starting the *roundout* (breaking the glide, para 7-29 below). If the pilot allows the airspeed to increase above normal, the airplane tends to "float" during the roundout while dissipating airspeed. If he allows airspeed to decrease below normal, the roundout may be impossible to complete.

7-29. Normal Landing

The normal landing for conventional type airplanes is a three-point, full-stall landing. The landing is accomplished into the wind to effect a slower groundspeed at touchdown. The airplane attitude is changed from normal glide to three-point (fig. 7-17). The rate of descent is decreased until the airplane flies parallel with the surface of the runway. This change of attitude and flightpath is called the *roundout*.
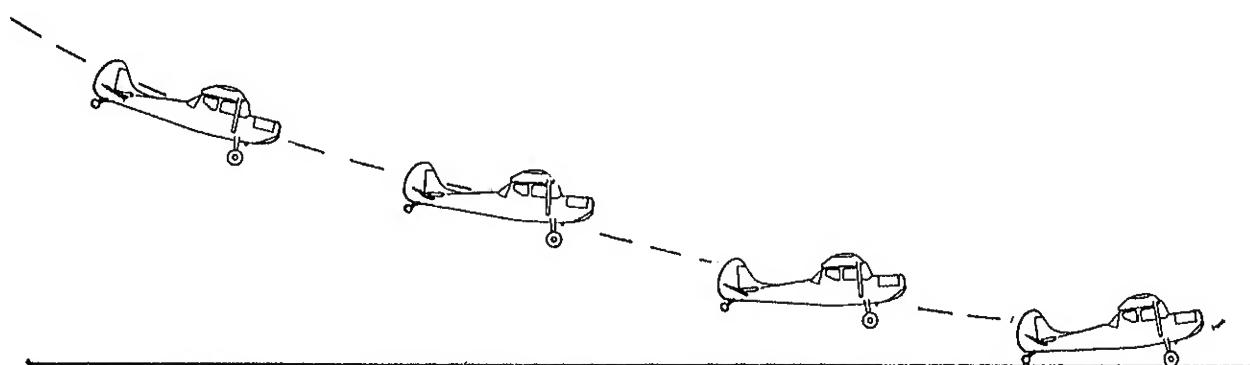

Figure 7-17. Normal landing.

a. The roundout must be started and timed to attain three-point attitude, stall, and touchdown almost simultaneously. Application of stick back pressure increases pitch attitude and dissipates airspeed. Stick back pressure is continued smoothly, only with enough force to prevent the airplane from striking the ground prior to obtaining a three-point attitude. At this time, the airplane should be only inches from the runway, stalled, and almost instantaneously making ground contact.

b. If the roundout is too fast, the airplane will "balloon," causing a gain of altitude. Since airspeed is dissipating, the airplane may stall

at considerable height above the ground. If ballooning occurs, the pilot must compensate with a relaxing of back pressure to get the airplane back to the runway in a three-point attitude before the stall occurs. This may require application of power to prevent the stall, or because of shortened landing space, the pilot may have to effect a *go-around* (para 7-30) for another approach.

c. If the roundout is too slow, the airplane will strike the ground while descending and either bounce back into the air, possibly damaging the landing gear, or crash. If the airplane touches the runway before stalling, with

descent unchecked, it will richochet off the ground with results similar to ballooning. Recovery is effected in the same manner.

d. The pilot must maintain directional control of the airplane after wheel contact with the runway. Ground steering is by means of rudder, steerable tail wheel, and brakes. If available runway permits, the speed of the airplane is allowed to dissipate with normal ground friction and drag. Brakes are used if needed to help slow the airplane. If necessary, maximum braking can be used immediately after touchdown, gradually releasing brake pressure as speed decreases in order to prevent nosing over.

e. Tricycle landing gear generally simplifies the landing; the touchdown should be made on the main gear with the tail low. The location of the center of gravity forward of the two main wheels combines with the forward momentum of the airplane to help hold the airplane on the ground. It also tends to keep the airplane rolling in a straight path.

7-30. Go-Around Procedure

A go-around is a procedure for remaining airborne following a decision to discontinue an intended landing. Go-arounds are used when the control tower landing clearance is withheld, when for any reason the approach does not develop as planned, and as an extreme measure in recovering from a poor landing.

a. Go-arounds in a controlled traffic pattern are usually initiated upon instructions from the tower, and are limited to maintaining or regaining pattern altitude and spacing in accordance with local traffic rules. Alertness for other traffic is of prime importance.

b. The majority of go-arounds are initiated on the timely decision of the pilot, at any time prior to completion of the landing roll. Both the decision and the implementing action must be timely—a late start may result in failure to clear a barrier or an accidental stall in the climb.

c. Go-arounds frequently occur in limited or confined areas requiring an accurate awareness of airplane and pilot performance limitations. The problem is basically one of building up speed and altitude within the limitations imposed by available power; preoccupation with either factor will result in a loss of the other. Maximum performance requires a thorough familiarity with the airplane's behavior under a variety of atmospheric conditions, flap configurations, and airspeeds.

d. Go-arounds are sometimes used to salvage a bounced, dropped in, or crabbed landing attempt. Such situations may involve directional control and stall recovery problems, which may consume considerable space before the climbout can be started. Serious structural damage is possible in any hard ground contact; it may be wiser to land rather than risk further flight in a weakened or uncontrollable airplane. There is no easy rule of thumb; each situation must be decided upon its merits.

e. Go-around techniques vary greatly with the airplane type, the proficiency of the pilot, and the situation in which he is placed. To cover all cases would be impracticable. The following cautions are for pilots of light, single-engine, fixed-pitch propeller airplanes.

(1) *Decide—then act without delay.*

(2) *Ease the throttle forward—don't ram it on.*

(3) *Carburetor heat must be off for full power.*

(4) *Extended flaps demand flat climb attitudes—the more flaps, the lower the nose.*

(5) *Retract flaps gradually—and only after a safe speed is attained.*

(6) *Speed is always the first element of control—be alert for a stall.*

(7) *Beware of a go-around with a disabled airplane.* If this occurs, the situation will dictate the best procedure. Extent of the damage will govern whether to defer landing until a favorable area is reached. If control response is abnormal, a climb to a safe maneuvering altitude will permit detection of adverse landing characteristics while retaining the option to bail out. A call to the tower will bring expert advice and alert the crash crew.

CHAPTER 8

INTERMEDIATE FLIGHT MANEUVERS

Section I. INTERMEDIATE GROUND TRACK MANEUVERS

8-1. General

Pilot sensory perception of the airplane and trained reactions are continuing requirements on an Army aviator's skill. In this respect, ground track maneuvers must be practiced throughout an aviator's career.

8-2. 8's Around Pylons

This maneuver primarily is designed to develop planning and *sensory-type flying*. Two *plyons* (identification points) are selected on a ine perpendicular to the wind. The two pylons need not be identical, but both should be easily discernible. Trees, spires, fence corners, water tanks, etc., may be used for pylons. A symmetrical ground track is flown around the pylons while maintaining a constant altitude above the terrain. The ground track is in the shape of a figure 8; the two pylons are centered in the loops of the 8 (fig. 8-1).

a. The maneuver is begun by flying downwind between the two pylons or by flying parallel to the pylons on the downwind side. After about 270° of turn, the airplane is rolled out into straight and level flight and flown between the two pylons, downwind, at about 45° to a line connecting the two pylons. As the plane approaches a point where a pylon becomes perpendicular to the flightpath, a turn is started around the second pylon. This turn
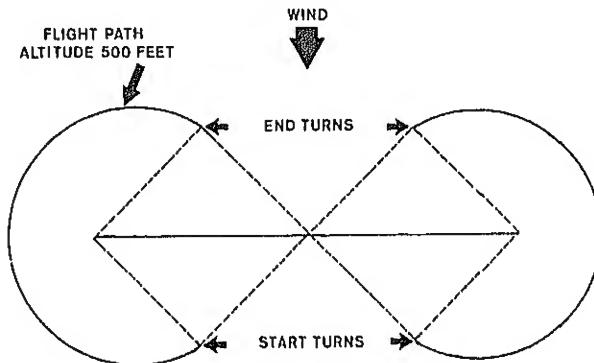

Figure 8-1. 8's around pylons.

is continued for approximately 270°, at which time the airplane is rolled out straight and level and flown between the pylons at about 45°, downwind, to a point where the first pylon approaches the perpendicular to the flightpath. A turn is then started around the first pylon again. The amount of bank used in the turns varies as necessary to maintain a constant-radius circle about a pylon.

b. Figure 8-1 shows roll-in and rollout. A fixed reference point on the airplane will not help the pilot during this maneuver since, generally, a constant reference to the pylon while flying the desired ground track is impossible except in a no-wind condition.

Section II. INTERMEDIATE AIR WORK

8-3. General

The maneuvers explained in this section serve a definite purpose in the career of the Army aviator in developing coordination between mind and body and providing knowledge which is helpful in everyday flying and flight emergencies.

8-4. Precision Turns—720°

All turns should be made with precision. Turns of 90° or 180°, using shallow or medium banks,

require good coordination for precision accomplishment. However, to continue a turn through 360° or 720° requires a higher degree of perfected coordination and more exact understanding of control functions. The requirement is still more pronounced if a steep bank is used.

a. A turn of 360° or 720° using a steep bank (generally 60°) is referred to as a *power turn* or a *steep turn*. Steep turns involve the use of all flight controls, generally including throttle to maintain necessary airspeed. Entry into a steep turn is like other turn entries, but it is continued until a steep bank has been established. As the bank progresses past that of medium, power is slightly increased to prevent overreduction of airspeed. The turn is continued through 720° and rolled out on the original heading. Controls are coordinated from entry to completion of rollout, to avoid slips or skids, with altitude constant.

b. Uncoordinated control will show up quite readily in this maneuver. A definite increase of back pressure, in addition to increased power is required to maintain altitude. Regaining lost altitude is a most common requirement. Excessive back pressure during the steep turn does not provide the desired noseup effect and can result in accelerated stalls. The correct technique for altitude control requires that the bank be shallower while holding back pressure to raise the nose. A climb can be stopped, or nosedown pitch achieved, by increasing the bank while maintaining back pressure. The basic technique of adjusting pitch by changing bank, as developed during steep turn practice, is necessary to accomplish advanced oblique turning maneuvers such as chandelles and lazy eights. Precision rollout requires expert control touch. Back pressure must be released as the bank decreases, with coordinated aileron and rudder pressures. Power is reduced after normal cruising airspeed has been regained.

8–5. Spirals

A spiral is a gliding turn of 360° or more, usually at a steep bank. The two main types of spirals are the constant bank-and-speed spiral and the spiral about a point. Each type develops and helps maintain flying proficiency.

a. A constant bank-and-speed spiral helps develop control touch and coordination for power-off conditions. It is entered from a normal glide. After a steep bank is established, the spiral may be maintained for any desired number of turns. Rollout may be on a predetermined heading or altitude. Coordinated controls are used at all times during entry, spiral, and rollout, with airspeed constant. During the spiral, bank is constant.

b. In the spiral about a point, the aviator selects a reference on the ground and flies the airplane to an advantageous position from which a circular ground track of about 1,000-foot radius can be entered. A normal glide is started, and the airplane is banked as necessary to maintain desired ground track. Elementary-8 fundamentals are applied to this type spiral to accomplish the constant radius circle about the point. The flight controls are coordinated at all times, and rollout may be on a predetermined heading or altitude. Because of ground orientation requirements, the spiral about a point requires *greater division of attention* than the constant bank-and-speed spiral.

8–6. Slips

A slip is a combination of forward and sideward movement, the lateral axis being inclined and sideward motion of the longitudinal axis being toward the lower side. Slips are used for crosswind landings (para 8–9) and to dissipate altitude without increasing forward speed. They are so controlled by the aviator as to make the airplane move sideways or to continue the initial flightpath over the ground, and may be used during a turn.

a. To establish a slip from a normal glide, the wing toward the desired direction of slip is lowered by use of ailerons. Rudder is used to hold the desired ground track, which may or may not require a change of heading. Gliding speed should be maintained during the slip.

b. Slips are extremely useful if the airplane has no flaps or if the flaps fail to function properly. In the event of a forced landing, the

slip enables landing in a field which is surrounded with obstacles that hinder a normal approach. Accuracy of landings also may be improved by use of a slip. The slip, however, is not normally used to increase approach angles in airplanes equipped with flaps.

Section III. CROSSWIND TECHNIQUE

8—7. General

It is impractical to build an airfield with sufficient runways to meet all wind conditions. When using small airfields with a limited number of runways or a strip with only one runway, proper crosswind technique must be employed.

8—8. Crosswind Takeoff

a. Proper application of controls during crosswind takeoff (fig. 8–2) is necessary to maintain aircraft control. Should the airplane inadvertently become airborne from a wind gust, the pilot must maintain straight ground track by lowering the wing into the wind. In effect, the airplane is slipped into the wind (B, fig. 8–2) only enough to offset wind drift. This results in a straight ground track parallel to the longitudinal axis and prevents a side stress on the gear if the airplane returns to the runway. After the airplane becomes positively airborne, the slip is removed as a crab (D, fig. 8–2) is established to correct for drift and allow a faster rate of climb.

b. Use of ailerons is the same as when taxiing crosswind, with elevators used initially as in normal takeoff. Rudder is applied to maintain a straight ground roll. As the roll increases in speed, aileron pressure is decreased to prevent the upwind wing from dipping excessively at liftoff; the wing should, however, be allowed to lower sufficiently to compensate for the wind. The airplane should be held on the ground slightly longer than in a normal takeoff; this will assure its remaining airborne when it leaves the ground.

8—9. Crosswind Landing

Successful landings under crosswind conditions are largely dependent upon the aviator's ability to fly by sensory perceptions. The aviator must be able to recognize errors and make intuitive corrections. Crosswind capabilities differ with different airplanes, but corrective methods are identical. The two methods used are the *wing-low* and *crab*.

a. The wing-low method is a slip; it is accomplished by lowering the upwind wing into
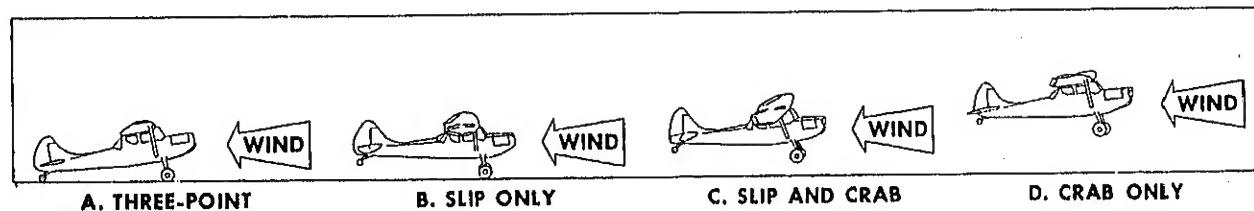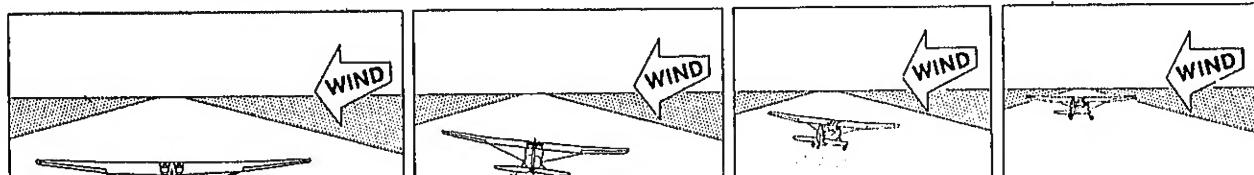

Figure 8–2. Crosswind takeoff.
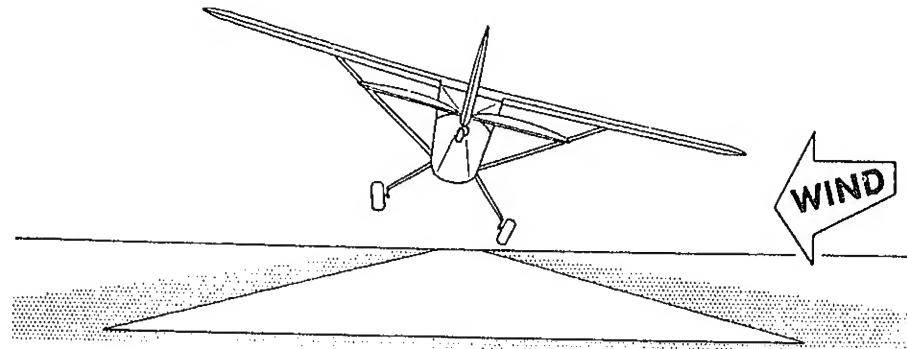
Figure 8-3. Crosswind landing—slip.
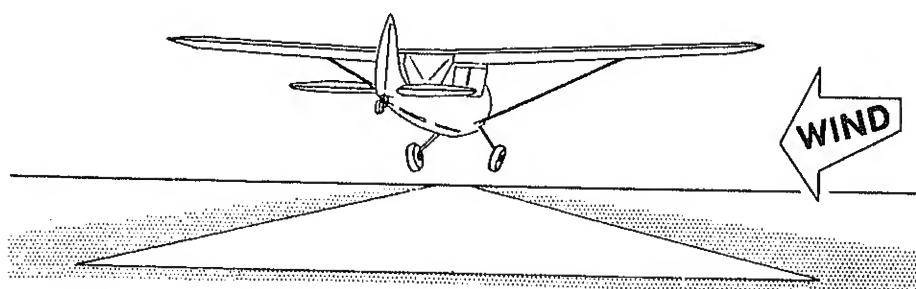
Figure 8-4. Crosswind landing—crab.

the wind just enough to compensate for drift (fig. 8-3). The slip normally is established during the final approach. It is then maintained as necessary throughout the approach and roundout. The airplane will initially touch down on the upwind main wheel, and as speed decreases, it will settle onto the other main wheel.

b. The crab method (fig. 8-4) is more difficult since better timing is needed during the roundout. The aviator maintains required crab for the wind condition throughout the final approach. Just prior to touchdown, he removes the crab and lines the airplane up with the flightpath. If the crab is not completely removed prior to touchdown, side loads will be imposed on the landing gear that may result in gear damage or loss of control. If the crab is removed too soon, the airplane will drift off course.

c. A combination of the methods in *a* and *b* above may be employed—the crab for the approach, changed to a slip for roundout and touchdown. This combination method is usually preferable in light airplanes.

Section IV. ACCURACY LANDINGS

8-10. General

Perhaps the most demanding requirement of Army aviators is that of landing on a predetermined spot with precision, and doing it repeatedly. Proficiency in accuracy landings is mandatory as a training maneuver, and its value cannot be overemphasized for emergency landing proficiency.

8-11. Side and Overhead Approaches: 180°

a. The most commonly used approach in Army aviation is the 180° side approach (fig.

8–5). Power is reduced on the downwind leg opposite the desired point of touchdown, and a glide is established for the remainder of the pattern. After power is reduced on the downwind leg, the length of the power-off approach of the downwind leg, the base leg, and the final approach should be approximately equal. However, if the downwind leg is too far from the field, the base leg must be closer in than normal. This approach, as all the others, requires accurate judgment of gliding distance for the existing wind and weather conditions.
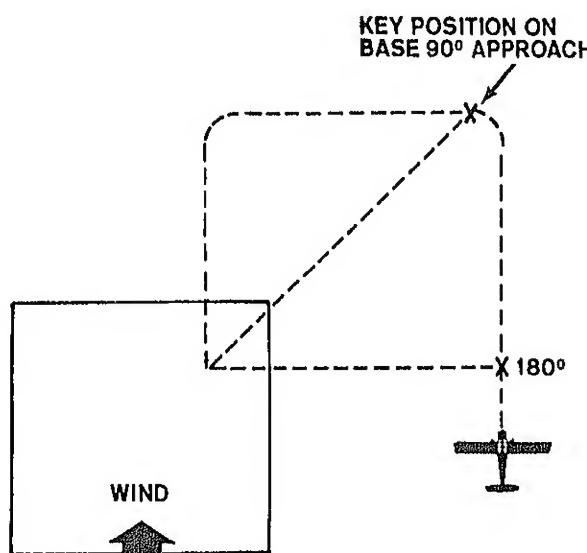

Figure 8–5. 180° side approach.

b. The 180° overhead approach is initially more difficult to judge since it requires more turns. Power is reduced while flying downwind, directly over the point of touchdown (fig. 8–6). The airplane is then turned 45° off the downwind track in either direction and this heading maintained until ready to turn onto a base leg. This turn is 135° and must be started soon enough to roll out on base leg with sufficient altitude to continue a normal approach without power. If the base leg is too close or too far from the field, the aviator must take supplementary action to accomplish the landing on the predetermined spot. This may require either an early or delayed turn onto final approach.
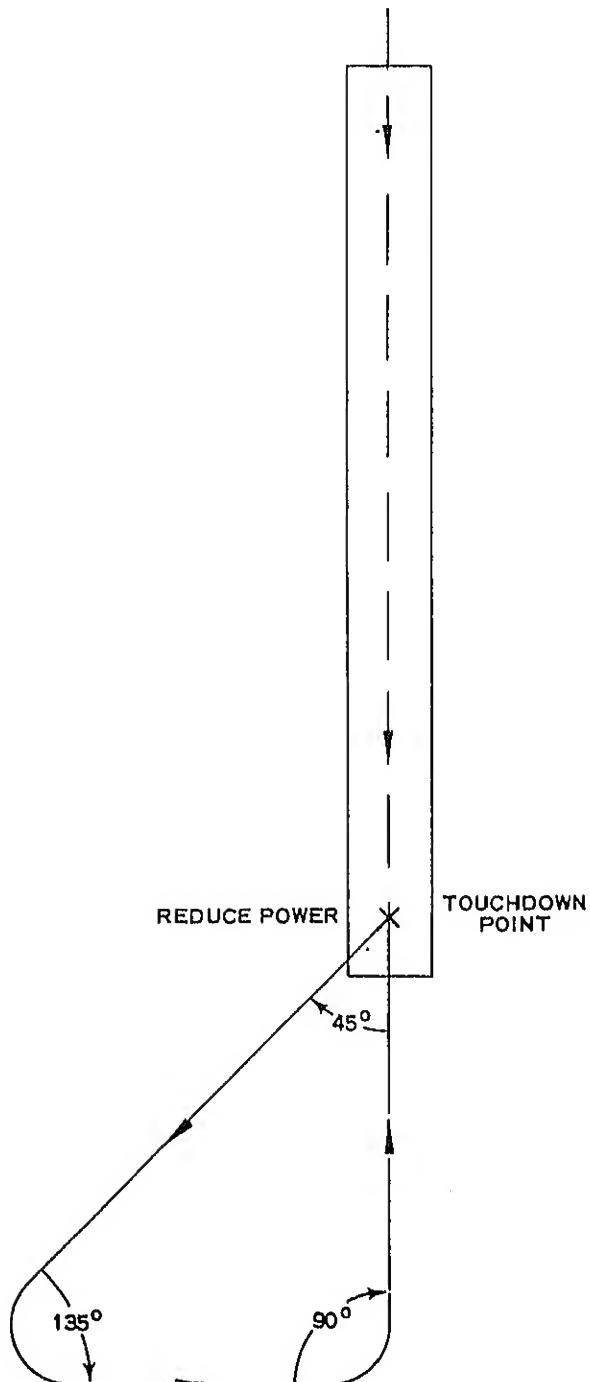

Figure 8–6. 180° overhead approach.

8–12. Overhead Approach: 360°

The 360° overhead approach is not often used for a normal landing. However, this approach is used by the aviator to maintain proficiency in glide judgment. The pattern for this approach is shown in figure 8–7. Flying in the same direction in which the landing is to be accomplished, power is reduced over the desired point of touchdown. A glide is then established for the remainder of the approach. The first turn is 135° in either direction and executed as power is reduced and the glide established. The remainder of the pattern is the same as the 180° overhead approach, the second turn being 135° to place the airplane on base leg. The base leg may then vary as necessary to compensate for error in judgment and to allow arrival at the point of touchdown.
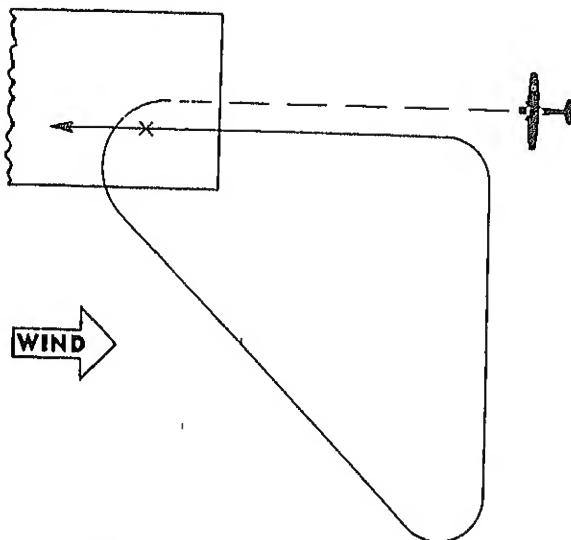

Figure 8–7. 360° overhead approach.

8–13. Spiral Approach

The spiral approach normally is used only in the event of a forced landing. Its advantages are limited to particular situations; e.g., over swampy or wooded terrain with only one available landing area. The chance of probable error in judgment is lessened, since all maneuvering is done in the immediate vicinity of the landing area and touchdown point. The spiral, which usually is performed about the point of touchdown, can be broken off into a

pattern for a normal approach from any position at the selected altitude. A steep spiral will result in a fast loss of altitude, while a shallow- or medium-banked spiral will lessen the rate of descent and give the pilot more time for continued planning and execution of the appropriate emergency procedures.

8–14. Wheel Landings

Wheel landings are primarily useful in high or gusty winds. They provide conventionally geared airplanes with one of the advantages of the tricycle gear by maintaining ground contact at a low angle of attack. This minimizes the possibility of being lifted off by gusts during the initial ground roll while airspeed is being dissipated.

a. In execution, the approach and landing require good coordination of throttle and elevator to counteract turbulence. Above normal approach speed is also desirable to improve flight control. Contact with the runway should be made at a negligible rate of descent, in level flight or slightly tail low attitude. Following touchdown, ground contact is maintained with elevator control. Power is used as necessary to cushion subsequent touchdowns on rough terrain, and in extreme cases it is used to maintain control in a static position until aid is received from ground personnel.

b. Flaps should not be used in winds which approach the stalling speed of the airplane. If a wheel landing is intended, the approach speed should never be reduced to a point requiring a near three-point touchdown. Use of power is optional during the approach as an aid to accuracy. To minimize ground roll, power should be eliminated smoothly immediately after touchdown.

c. Normally, unless necessary for directional control, brakes are not used until three-point attitude has been achieved; however, brakes can be safely used during rollout as long as elevator control remains effective. If brakes are required due to limited area, a three-point landing generally is advisable.

d. Control is most critical during the transition from level flight attitude to a three-point attitude, due to reduced control effectiveness at that time. The tail must be allowed to de-

scend steadily during speed reduction. Holding it up too long may result in loss of directional control, while pulling it down too soon may cause an inadvertent ballooning. The tail should be allowed to fall without help or hindrance. When the tailwheel is down, the stick should be eased back to keep the tailwheel on the ground if a three-point attitude is to be maintained. In strong headwinds, full up-elevator may not be desirable; it is better that the tail should rise during a strong gust rather than the entire airplane.
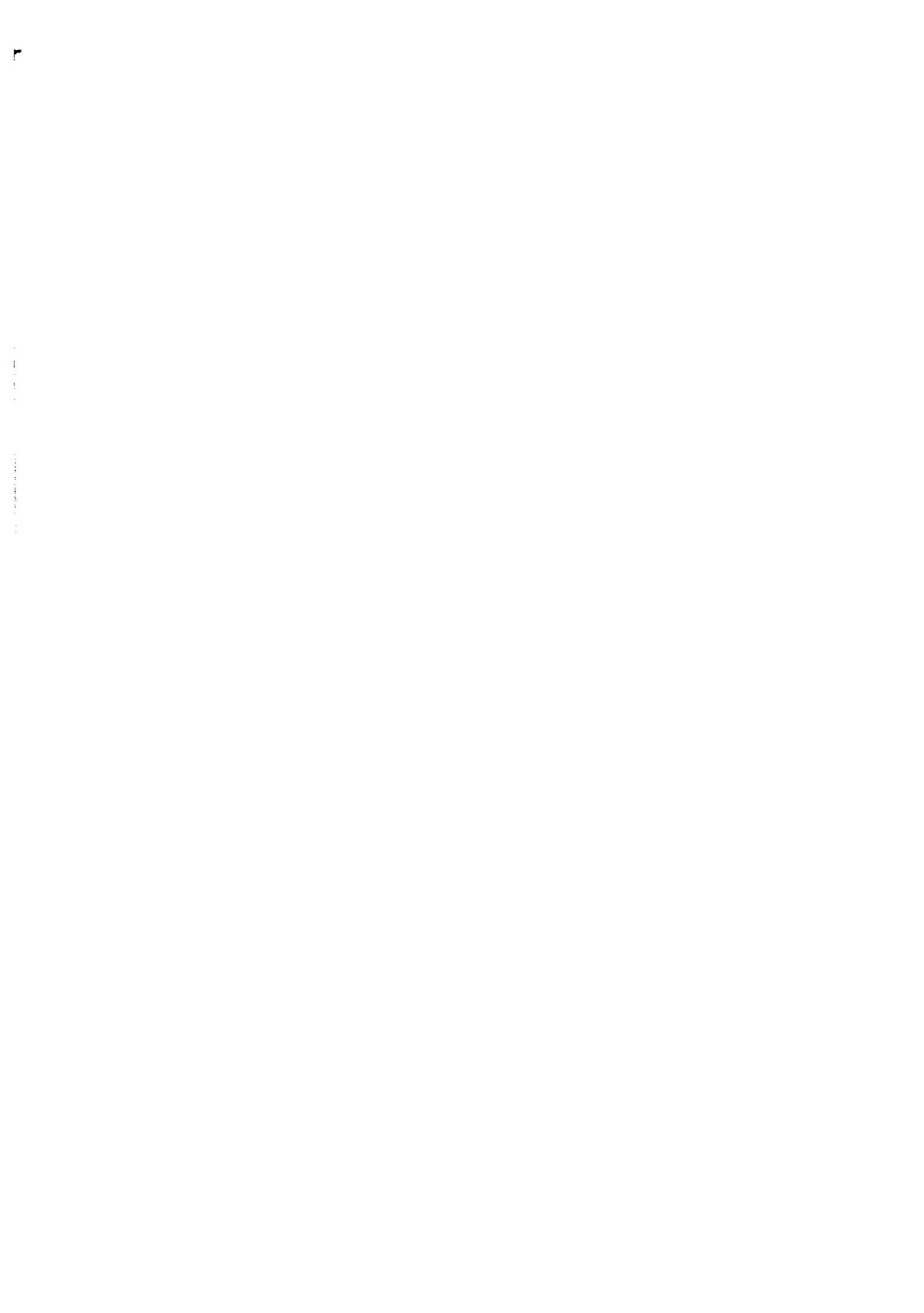
CHAPTER 9

ADVANCED FLIGHT MANEUVERS

Section I. ADVANCED GROUND TRACK MANEUVERS

9–1. General

Successful completion of many Army aviation missions is directly dependent upon the aviator's ability to fly by sensory perceptions. Practice of air-ground visual perspectives helps develop this capability.

9–2. Steep 8's Around Pylons

The major principles of flying 8's around pylons (fig. 8–1 and para 8–2) are the same, whether they are shallow or steep; the only difference is the amount of bank required.

Steep 8's generally use a circle one-half the size of the normal 8. To lessen the amount of straight and level flight between pylons, distance between pylons can be reduced. Since the circle about the pylon is smaller, slight errors are more noticeable. Consequently, more attention must be given to the ground track. This requires a higher degree of sensory-type flying. Proper performance of this maneuver is dependent upon a reasonable degree of proficiency in the normal 8 around pylons.

Section II. ADVANCED AIR WORK

9–3. Chandelles

The chandelle is an advanced maneuver in which the airplane is flown at varying airspeed, power, bank, and pitch attitude. The maneuver normally involves airspeeds ranging from above normal cruise to just above stalling. The banks will vary with the available power of the individual airplane. The more power available, the less the bank requirement, and consequently, the greater the altitude gained. The chandelle involves a 180° change of direction; it consists of a portion of a loop in an oblique plane, followed by a climbing rollout.

a. From straight and level flight at normal cruise, the maneuver (fig. 9–1) is started by going into a shallow dive. After building up excess airspeed, the airplane is banked in either direction while still in a nose-low attitude. The degree of bank will determine height of pattern, altitude gain, and power requirements. Airplanes with small power reserves must use correspondingly steeper banks than airplanes with greater reserve power. Banks too shallow

for available power cause stalls due to excessive climb; banks too steep allow termination of the maneuver with excess speed. When proper bank has been established, it is held constant and back pressure is applied to start a climb. As the airplane starts the climb, it will turn and the bank will appear to steepen. Power is added as airspeed decreases in the climb. After turning 90° from the original heading, the acquired pitch attitude is held constant, and the bank is removed slowly so that, after turning another 90°, the wings are level and the airplane is in a nose-high attitude, with airspeed just above stalling.

b. At the halfway mark when the rollout is started, the throttle should be at maximum allowable power. After turning 180° and leveling the wings, the nose is lowered slowly for airspeed to build up to normal cruise without losing altitude. As airspeed increases, throttle is slowly reduced to prevent engine overspeeding. When normal cruising airspeed is reached, power should be further reduced to normal
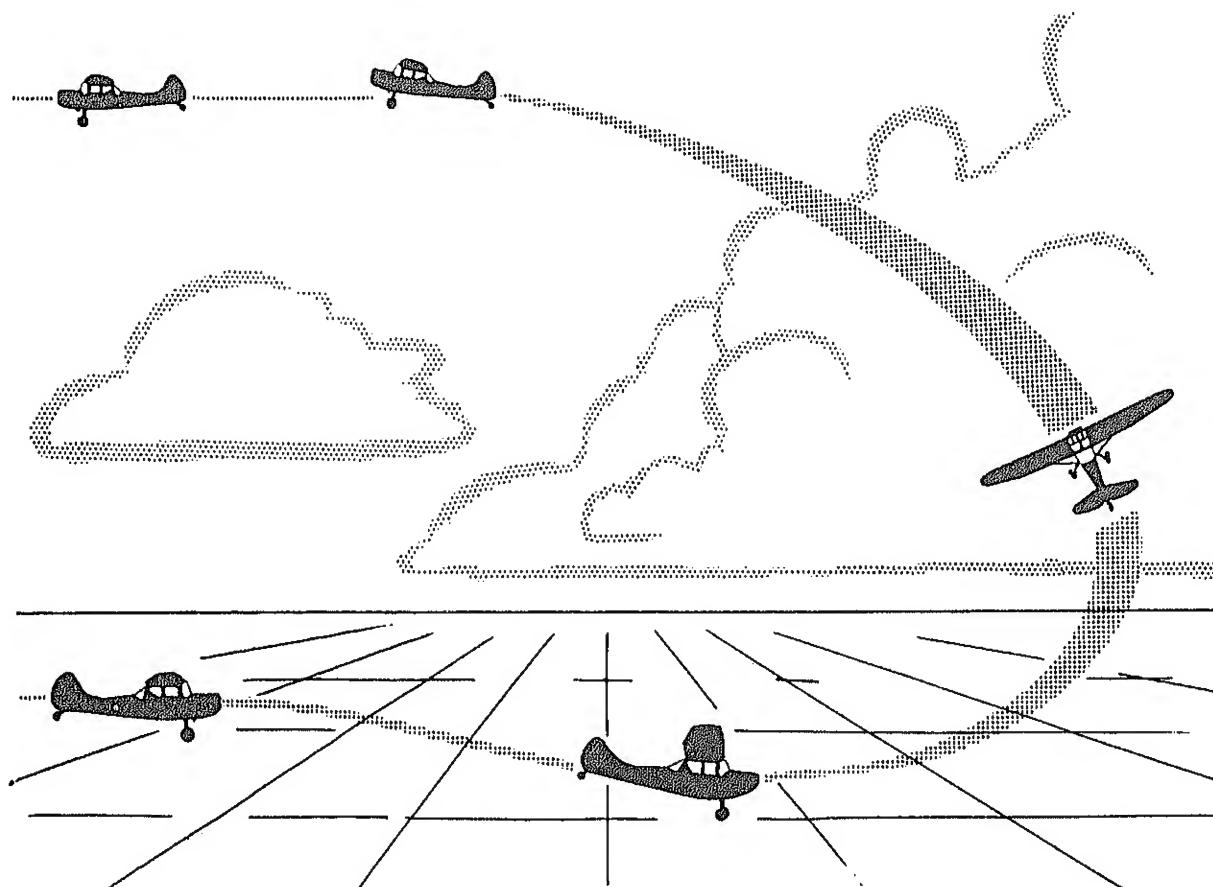
Figure 9–1. Chandelle.

cruise. Coordination must be precise throughout the maneuver. Although the chandelle is often called an altitude-gaining maneuver, the overall net gain should not be a primary criterion for its performance. Loss of altitude during the initial dive, plus lack of required power in some airplanes, limits appreciable increase in altitude during the maneuver.

9–4. Lazy Eights

The lazy eight is an advanced coordination exercise. Unlike the chandelle, it is wholly a training exercise. For its execution, the airplane is flown through a wide range of airspeeds and bank and pitch attitudes, with constantly varying control pressures. The lazy eight is unrelated to other 8's previously described because it does *not* describe a figure 8 over the ground, and ground track is irrele-

vant. The lazy eight (fig. 9–2) is described by the projection of the longitudinal axis on the horizon and is apparent only to airplane occupants.

a. The lazy eight consists of two 180° turns in opposite directions, entering one from the other, with a symmetrical climb and dive during each turn. The only straight and level attitude during the maneuver is at the moment of passing from one turn to another.

b. To help achieve symmetrical loops in the two turns, a reference point is selected on the horizon 90° from the direction of flight (the cross in fig. 9–2). During the maneuver, the lateral axis will appear to descend through the reference point as the turn is started, and the longitudinal reference will appear to descend through the ground reference point diagonally, *at* the 90° point of the turn.
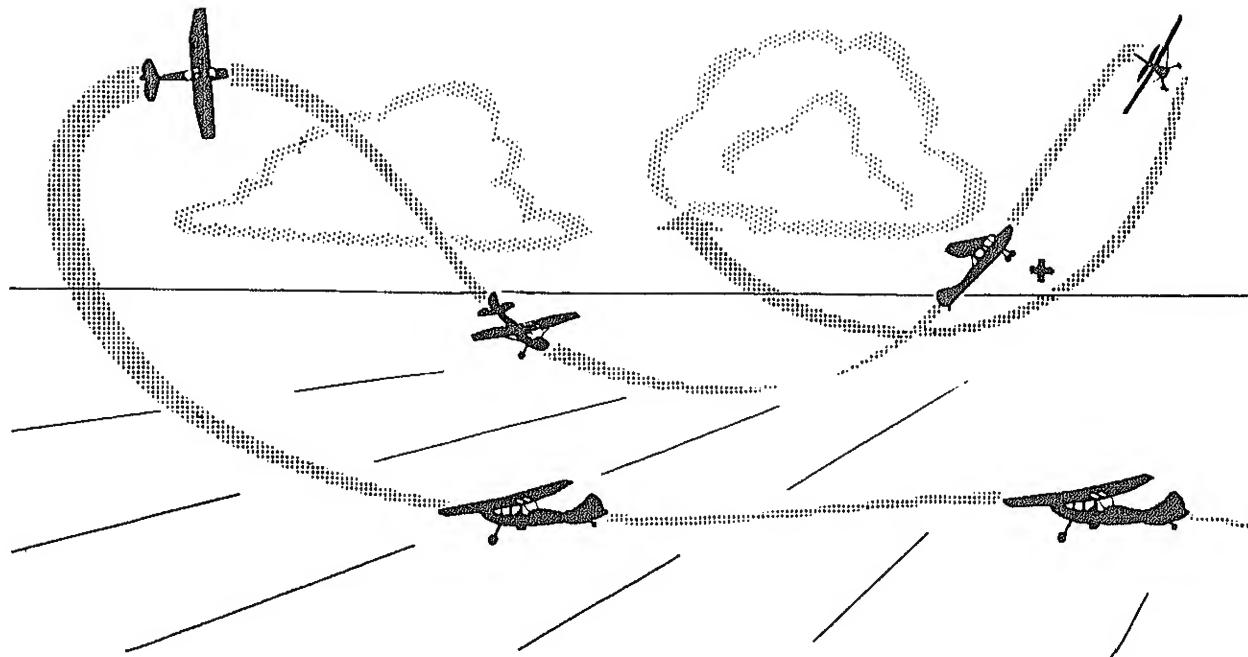
Figure 9–2. Lazy eight.

c. The maneuver is entered while flying crosswind at the established entry speed. A climb is started and a turn is begun toward the reference point. At this time, the inside wingtip (or lateral axis) will appear to pass down through the reference point. Bank is constantly increased through the first 90° of turn. After 45° of turn, the pitch attitude should start decreasing until the longitudinal axis is level after 90° of turn; the longitudinal reference on the airplane will then appear to pass through the ground reference point.

d. At this time a slow rollout is begun. The nose continues downward, entering a dive. As airspeed again builds and bank decreases, the nose will stop descending and start upward. As it passes through level flight, the wings should be level with the airplane flying 180° to the original heading.

e. Without pausing at level flight, a climbing turn is started in the same manner as in c above but using an opposite bank, and the same pattern is flown again. At the completion, the airplane will be on the same heading as when the maneuver started.

f. Throughout the maneuver, the airplane should be flown with precision. Continual small corrections usually will be required and should be made using control combinations to maintain coordination. Because of the requirement of constantly varying control pressures, practice of this maneuver develops control touch.

9–5. Precision Spins

Precision spins are essentially elementary spins, the entry and spin being executed in an identical manner. However, precision spins require better use of controls and spin orientation. The precision spin normally requires recovery on a specific heading after a preselected number of turns, with minimum slipping and skidding during recovery.

9–6. Accidental Stalls and Spins

When an aviator fails (through preoccupation) to recognize an approaching stall in time to avert it, the resulting unintentional stall may lead to a spin. If the spin occurs near the ground, altitude may be insufficient for recovery, with the accidental stall ending in disaster.

a. Accidental stalls and spins may result from improperly executed steep turns, or from an increase in load factor and stalling speed due to an increase in bank (para 4-4). When close to stalling speed, slight application of rudder may cause an airplane to spin. If top (outside) rudder is applied, the airplane will spin opposite the direction of the turn (over-the-top); if bottom (inside) rudder is applied, it will spin in the direction of the turn (under-the-bottom).

b. Probably the most disastrous of all inadvertent spins occurs when turning into the approach leg of the traffic pattern. Being close to the ground, the aviator may be somewhat dubious of using a steep bank to accomplish the necessary rate of turn to aline with the runway. He may try to tighten the turn with bottom rudder without increasing bank. This will cause a skidding turn that. leads to a violent under-the-bottom spin. Conversely, if outside rudder were used to decrease the rate of turn, a slip would result. If a stall occurred during this slip, an over-the-top spin could result. To accomplish a safe turn, airspeed must be kept well above stalling and the controls must be well coordinated at all times.

c. Accidental stalls and spins are not limited to turning situations; they may occur in any flight attitude.

CHAPTER 10
TWIN-ENGINE AIRPLANE

10–1. General

Several types and models of twin-engine airplanes are now used in performing the training and the operational missions of Army aviation. This chapter primarily concerns the most prominent of those flight characteristics of twin-engine airplanes that require additional aviator knowledge and skill.

10–2. Asymmetric Thrust

Asymmetric thrust is the principal flight characteristic of multiengine airplanes that must be counteracted. To accomplish the desired stability during power changes, most single-engine airplanes have the engine positioned to allow the thrust line to pass through or near the center of gravity. In conventional twin-engine airplane models, only the resultant thrust of both engines will provide this stability. When both engines are not operating at equal power, unequal (asymmetric) thrust results and causes yaw (movement about the vertical axis). The rudder is used to prevent this movement. If yaw occurs, the airplane may also roll or bank and both rudder and aileron are required to regain level flight.

★10–3. Minimum Control Speed (Vmc)

When one engine is inoperative and the other at takeoff power, maximum asymmetric thrust is created. When adequate airspeed is maintained, yaw can be prevented by rudder application. Below this airspeed, directional control can only be maintained by reducing power. This critical airspeed is identified for each airplane as the minimum control speed (Vmc). It is the minimum speed at which one engine can be rendered inoperative and straight flight continued with remaining engine operating at takeoff or maximum available power, flaps in takeoff position, landing gear retracted (unless

gear-down is specified) inoperative engine propeller windmilling, and center of gravity at rearmost position. When the most critical engine (the left one on U.S. airplanes) is rendered inoperative and the airplane is in the most unfavorable flight configuration, Vmc assures the ability to stop a turn and maintain the new heading. Vmc applies only to the control of asymmetric thrust and does not assure that altitude can be maintained or climb accomplished.

10–4. Climbs

a. In addition to normal climbs, the airplane operator's manual establishes the best angle of climb and the best rate of climb speeds. Climbing is by means of reserve power (the power available that is not required to maintain level flight). Under the most favorable circumstances with one engine shut down, a twin-engine airplane will not have an abundance of reserve power. Any change from the best rate and angle of climb will rapidly decrease climb performance. This means airspeed above, as well as below, the best single-engine climb speed.

★b. To provide excess power for climbing, drag should be reduced to a minimum by retracting landing gear, positioning flaps at cruise, and feathering the propeller of the inoperative engine. The exact sequence of events is determined by the flight situation and the type of airplane. Single-engine climb speed is the most efficient single-engine operating speed. If altitude cannot be gained at this speed, climbing is not possible without obtaining more power or reducing drag or weight.

10–5. Level Flight

a. The operator's manual provides power settings and ceilings for both normal and sin-

gle-engine cruise flight. The ability to maintain level flight with one engine inoperative is possible only below the single-engine absolute ceiling. This ceiling is based upon standard atmosphere, sea level conditions with the operating engine at maximum continuous power, maximum gross weight, gear and flaps up, and the inoperative propeller feathered. Factors that reduce the ceiling are high density altitude or failure of the propeller to feather. Airspeed is also a factor; *for example*, the best single-engine rate of climb speed provides maximum efficiency.

★*b.* An average power chart provides for cruise operation with 45 to 75 percent power. One engine alone may be required to operate above the recommended cruise range to supply the necessary power for continued flight. The loss of one engine creates an emergency, and flight should not be continued beyond the nearest suitable airfield. When operating with a single engine, trim controls usually are adequate to relieve control pressures. Some operator's manuals recommend a bank of 3° to 5° toward the operating engine during straight flight. Bank reduces the amount of rudder required to counter asymmetric thrust but results in a slip and a reduced vertical component of lift. Thus, degree of bank should be confined to recommended amounts.

10-6. Descents

Usually, descent is performed at a specified power setting and airspeed that will retain minimum engine operating temperature and avoid plug fouling or engine loading. Descents made at idle power for prolonged periods should be avoided since low manifold pressure and high rpm result in detuning of reciprocating engines, leading to premature engine failure. One inch of manifold pressure for each 100 rpm is the general rule for descent power; for specific information, consult the engine power charts in the operator's manual. Due to the low power requirements involved, en route descents with one engine inoperative present no problems. However, descent for landing is more involved and requires some precaution to avoid undue hazard.

★10-7. Approach and Landing

a. Approach speeds vary with airplane configuration and the type of approach. The operator's manual and pilot's checklist supply this information. When both engines are operating normally, no special technique or skill is required; however, performing the approach and landing with one engine inoperative demands more skill and judgment. When possible, normal patterns and speeds should be used with landing gear extension delayed until pattern position assures reaching the runway. To allow maximum use of power without loss of control, if needed for go-around or to prevent landing short of the runway, speeds above Vmc should be maintained until landing is assured.

b. If rudder trim has been used to counteract asymmetric thrust, retrim to neutral during the approach following power reduction.

CHAPTER 11

TACTICAL FLIGHT TRAINING

Section I. SHORT FIELD AND ROAD STRIP TECHNIQUE

11-1. Power Approach

a. The power approach is used to accomplish touchdown accuracy and the shortest safe ground roll. The shortest safe ground roll is accomplished by maintaining the slowest speed during the approach that is required to provide a safe margin above stalling. This airspeed will vary with different airplanes, loads, and weather conditions (e.g., temperature, relative humidity, and density altitude). To assure minimum safe airspeed consistent with prevailing conditions, an appropriate pitch should be established. This attitude is the highest pitch attitude which would sustain controlled flight with power removed, and commonly is referred to as "power approach" attitude. Use of attitude rather than airspeed allows the pilot to devote his attention outside the cockpit, yet provides for immediate recognition and correction of error on the glidepath. Angle of descent is controlled by the throttle, maintaining a glidepath which approximates that of normal glide.

b. There are many important factors to be considered by a pilot before landing in short, strange fields. Two of these are—

(1) *Touchdown point.* The touchdown point is the place on the ground selected by the pilot on which to land the airplane. It should provide maximum usable distance for the ground roll after landing. If barriers exist at the approach end of the landing area, the point of touchdown must be far enough away from the barriers to provide a safe approach angle over them.

(2) *Go-around point.* The go-around point is a point selected by the pilot from which either a safe landing roll or a safe go-around

can be executed. Its location will vary from a position on final approach prior to the touchdown point to a place farther down the landing area beyond the touchdown point, depending upon the wind, barriers, and length of usable strip.

c. The power approach *may be* started from *any position.* Usually a normal glide is used until the airplane is on the required glidepath, then the power approach is started. If the approach is made to an open touchdown point, the pilot must visualize the proper glidepath and maintain it. If there is a barrier at the approach end of the landing area, the pilot can use the sight picture method to help visualize and maintain the glidepath (A and B, fig. 11-1).

d. The roundout is started at the same point as in a normal power-off approach, but is executed more gradually since less change in pitch attitude and airspeed is required. Due to the slow speed at this point, a low, abrupt roundout should be avoided. It is started in sufficient time to simultaneously stop the descent, attain a three-point attitude, and make ground contact at the touchdown point. To prevent the airplane from floating, power reduction is started simultaneously with roundout; but it should be slow enough to prevent early stalling. Normal crosswind technique is used as required. After touching down, brakes are applied as necessary. If severe braking action is necessary, brake pressure should be applied immediately after touchdown.

11-2. Maximum Performance Takeoff

a. The maximum performance takeoff is designed for takeoffs from small, rough landing

AS VIEWED FROM DOWNWIND

AS VIEWED FROM
FINAL APPROACH

A. ARTIFICIAL BARRIER

AS VIEWED FROM DOWNWIND

AS VIEWED FROM FINAL APPROACH

B. NATURAL BARRIER
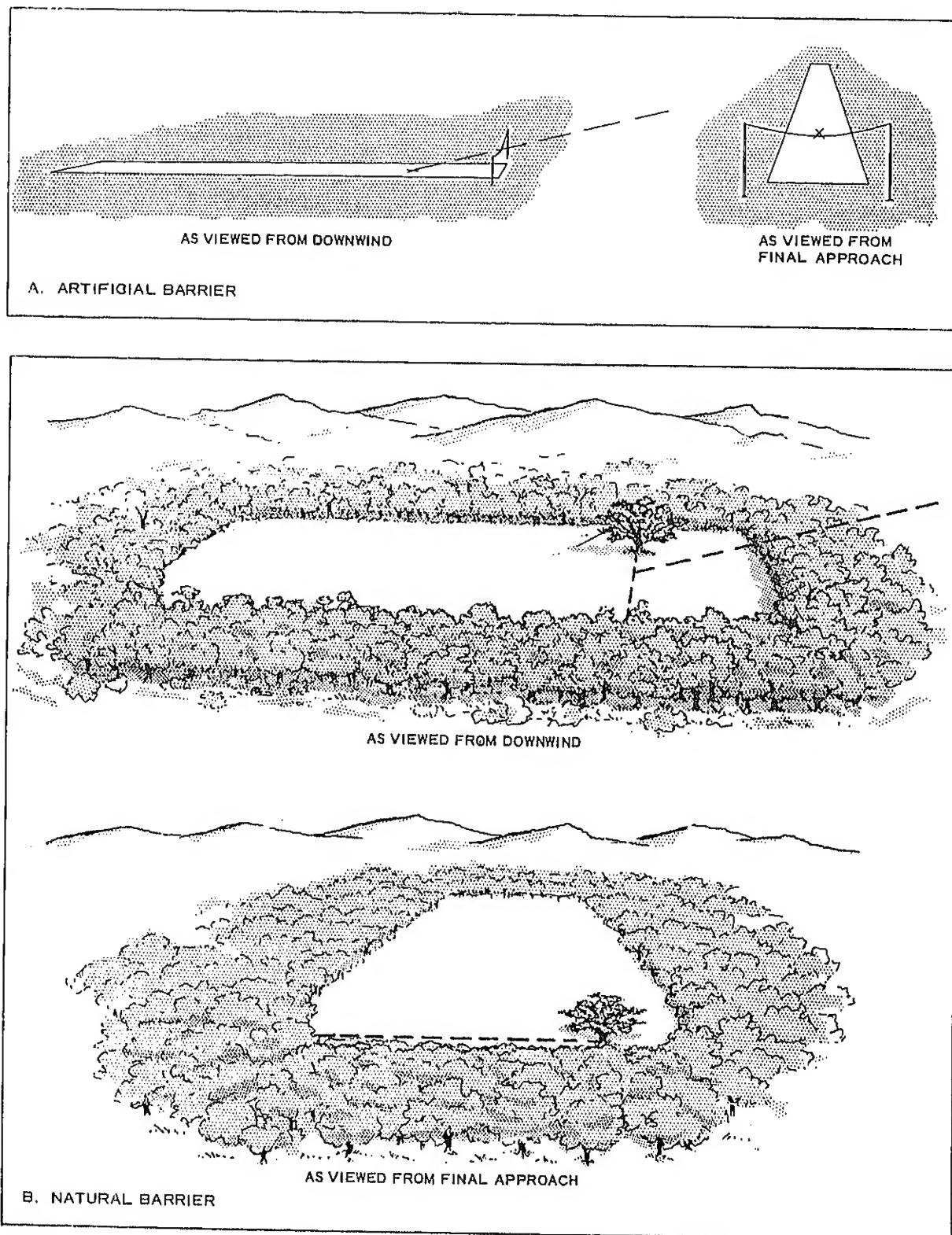
Figure 11-1. Barrier sight picture.

areas with minimum ground roll. Loss of ground drag allows the airplane to accelerate faster off the ground and leads to a normal limb in less horizontal distance than in normal takeoff.

b. For minimum ground roll, maximum permissible power is used. The throttle is advanced while holding the airplane in the takeoff position with brakes until maximum permissible power is reached. Ground roll begins by releasing the brakes; directional control is accomplished by use of the tailwheel or nosewheel and rudder. Further use of brakes is avoided except for emergencies.

c. The takeoff is made in a tail-low attitude. After leaving the ground, pitch attitude may be increased to achieve the maximum angle of climb for clearing a barrier. Once the barrier is cleared, a normal climb is assumed. If there is no barrier, normal climb is assumed after the airplane becomes airborne. Crosswind control is the same as in a normal takeoff. To obtain maximum lift, a crab is established as soon as possible after takeoff.

11-3. Flight Reconnaissances

Since much of the flying required of Army aviation is from unprepared strips that have other uses, the aviator must be sure that the strip is in usable condition before attempting a landing. This is determined by means of a thorough reconnaissance, which is divided into two phases—*high* and *low*. To prevent disclosing the location of the strip, these reconnaissances must be made with a minimum of flying commensurate with safe, accurate observations.

a. *High Reconnaissance.* During the high reconnaissance, the strip is surveyed as accurately as possible, checking its length, slope, direction, obstacles (on the ends or sides), and available forced landing areas (for both landing and takeoff). After considering these facts, the directions of landing and takeoff are tentatively selected, and tentative points of touchdown and go-around are chosen. The direction and area of flight for the low reconnaissance is also selected. If the strip is on a road, particular attention must be given to ditches, culverts, bridge and culvert abutments, power and tele-

phone lines (either parallel to or crossing the strip), and road signs which a wing or strut might hit. Traffic on the road must also be considered. No particular flight pattern or altitude is prescribed for the high reconnaissance.

b. *Low Reconnaissance.* The low reconaissance normally is made in the same direction as landing and takeoff. However, *in all cases, the low reconnaissance will be made in the safest direction that allows suitable observation of the strip surface.* The altitude (A, fig. 11-2) and flightpath (B, fig. 11-2) for the low reconnaissance is such that the pilot is able to see all of the strip. Altitude should provide a safe margin above the highest obstacle in the flightpath. Where to fly the low reconnaissance is governed by such factors as wind, forced landing areas, and obstacles. It is generally best to select a flightpath that will allow observation with a minimum of obstructions to vision at the lowest possible altitude. During the low reconnaissance, the surface of the strip is inspected for suitability of use (watching for holes, rocks, stumps, or anything else that may prove hazardous to a landing). If it is an area strip with more than one possible landing lane, only that portion of the area selected for the landing should be scanned; the remainder of the area can be better evaluated after landing. Discoveries during the low reconnaissance may necessitate changes to the original plan of landing. Newly discovered features must be analyzed, alternate possibilities weighed, and a sound decision made promptly in order to eliminate unnecessary flying about the selected landing site.

11-4. Gr~~~~ ~~~~~~~~~~~~~~
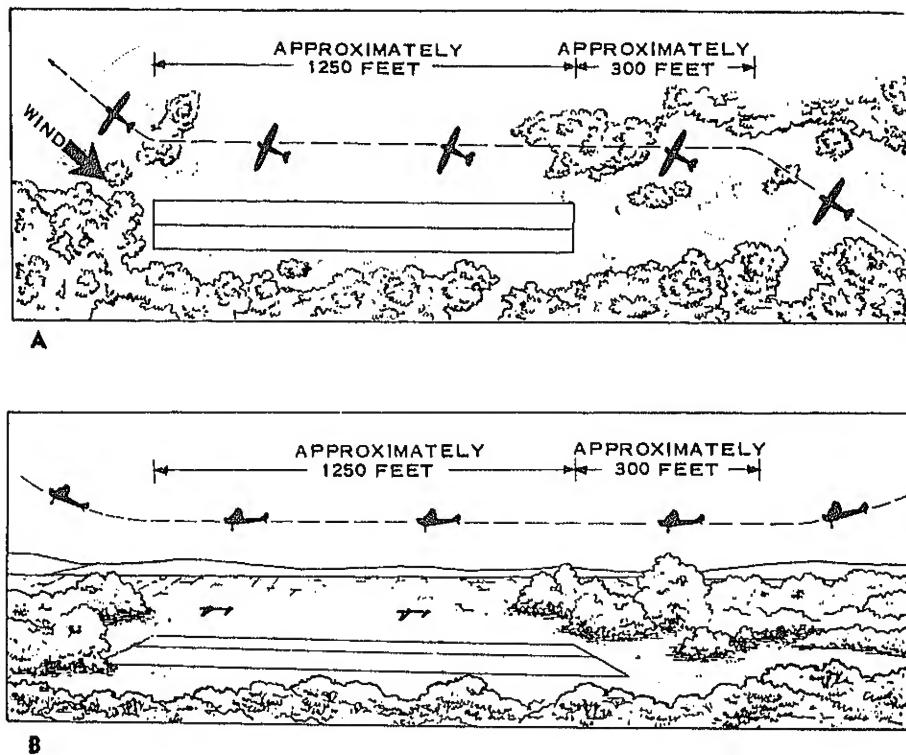
A ground
t~~~~~~

Figure 11-2. Low reconnaissance.

immediate takeoff is contemplated, wind direction is checked and takeoff direction confirmed. The best position for takeoff is selected and the takeoff *lane* doublechecked for safety.

Ground reconnaissance of road strips also includes checking ditches, culverts, lateral clearance, and turnaround areas.

Section II. FORMATION FLYING

11-5. General

Strict flight discipline, maintained by the leader, is necessary for the success and safety of the mission and is a requisite for effective formation flying. To maintain flight discipline, the leader must make correct decisions and take decisive action. For effective teamwork, he must receive unquestioned and immediate response from his wingmen.

11-6. Basic Visual Signals

During periods of radio silence, the leader exercises control over his formation by use of visual signals that normally are accomplished by movements of his airplane. The variety of airplanes and missions precludes the standardization of all visual signals that are used in formation flying; however, the following basic signals are widely used:

a. Gentle rocking of wings -- "Break up."

b. Rapid, slight elevator oscillations ---------- "Join up in standard formation" or Resume standard formation."

c. Rapid, slight rudder oscillations ---------- "Open up."

d. Dipping a wing (left or right) ----------- "Echelon left" or "Echelon right."

11-7. Formation Training

★*a.* The V-formation (fig. 11-3) is standard for training. It consists of a basic element of three airplanes which are flown by the leader (1) and the two wingmen (2 and 3). In-flight planning, including navigation and maneuvering clearances, is the responsibility of the leader; the wingmen obey his commands and maintain their relative positions so that the formation will move as a unit. Positions of the wingmen vary according to airplane type, weather conditions, and degree of pilot proficiency. Normally, wingmen will fly at above 45° angles to rear, above, and on opposite sides of the leader (fig. 11-3).
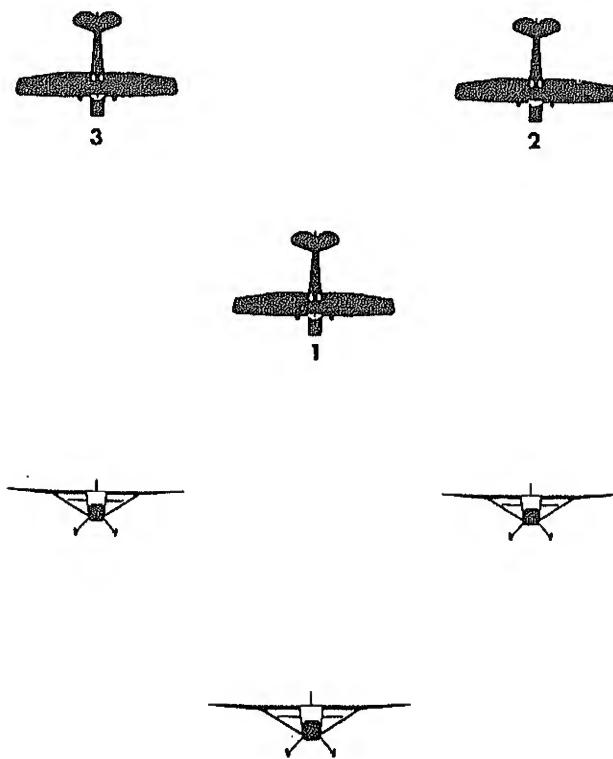
Figure 11-3. V-formation.

★*b.* The formation may join up by one of several methods. The usual method is by timed-interval takeoffs with rapid joinup. To join up, the leader uses a shallow bank to accomplish a wide turn. The wingmen cut inside the leader's turn, aiming 45° ahead of the nose of the lead airplane. Final positioning is accomplished gradually, with the leader kept in continuous view. Another method of joinup, but one less frequently used, is formation takeoff. Formation takeoffs require a high degree of skill, relatively large areas for movement, and contain an element of danger that can be avoided by using timed-interval takeoffs.

c. Success in formation flying depends on close cooperation between the leader and his wingmen. Both leader and wingmen must have complete confidence in each other. The leader plans well ahead, flies at a slightly reduced power setting, and makes all movements smoothly, avoiding rapid or abrupt changes in the flightpath. Power and speed adjustments are gradual and are held within the performance limitations of wingmen and airplanes. Although aviators experienced in formation flying execute movements without signals, distinct and easily understood signals may be advantageous for training.

d. The left wingman maintains his relative position with the leader. The right wingman dresses on the left wingman. All corrections in position are made immediately since falling behind the formation, with consequent use of full power to resume position, can result in fuel exhaustion before the mission has been completed. Wingmen remain alert to changes in the leader's speed and attitude, quickly following suit in bank, pitch, and heading. Small adjustments to lateral spacing are made with rudder; step-up, with elevators; fore-and-aft interval, with throttle. In executing turns, the outside airplane increases speed while the in-wingmen keep their slot positions, compensating in speed for different turning radii: the outside airplane increases speed while the inside one reduces speed.

e. The echelon formation (fig. 11-4) is one in which the wingmen are positioned in a diagonal line behind, to one side of, and above the leader. It is employed primarily to expedite formation breakup and landing.

(1) The individual airplanes may peel off at time intervals to provide precise spacing in the landing pattern. Where runway width allows, they may land alternately left and right, with minimum spacing in the pattern.

A. RIGHT ECHELON
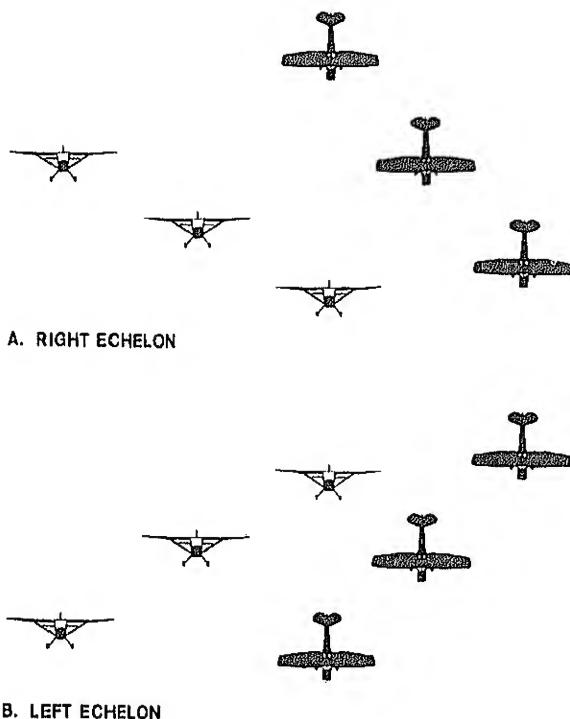
B. LEFT ECHELON

Figure 11-4. Echelon formation.

(2) The echelon is always formed away from the pattern (e.g., right echelon for a left-hand pattern). The shift from V-formation to echelon formation is executed on signal from the leader. For right echelon formation, the leader dips his right wing, then he and the right wingman hold steady while the left wingman doubles his step-up, changes his heading a few degrees to the right, and simul-sly reduces throttle so as to drop back ı new position above, behind, and to the ᵗ ᵗʰ~ ᵣᵢᵍʰt wingman. As he approaches ı, he resumes the initial head-setting.

ɣ from echelon formation to useful training maneuver al-

though seldom used in tactical formations. To accomplish this maneuver, the leader rocks his wings, then he and the first wingman hold steady while the second wingman changes heading a few degrees, adding throttle so as to advance as he crosses over to the new position. He maintains his initial step-up until properly positioned laterally and fore-and-aft. He then descends to the level of the other wingman.

f. The trail formation provides wingmen with practice in changing from one position to another. Emphasis is given to avoiding the slipstream of the lead plane and developing interval judgment. The practical value of trail formation is otherwise limited. Stepdown is hazardous if external loads are carried, and step-up may not be advisable because the nose of the airplane may restrict forward and downward vision. Separation which will allow for individual maneuvering should be maintained while flying in trail formation following peeloff for landing and takeoff for joinup.

11-8. Weather Minimums

For a specific mission, aviation commanders specify the minimum ceiling and visibility which must prevail in the departure area, en route, and in the objective area. At the time the operation is launched, the prevailing and forecast weather conditions should be equal to or better than the specified minimums. When less than specified minimums exist, the operation may be postponed or canceled, or the commander may decide to execute the mission despite the weather.

11-9. Safety

Preflight briefing by the mission commander will be detailed and complete, and will cover the nature of the mission, ground safety considerations, and emergency procedures to include course of action and possible results.

Section III. NIGHT OPERATIONS

ıl

complicated by impairment of ns in which day flying nor-

mally provides effortless judgment of distance, altitude, speed, and attitude. Allowing a margin for error and increasing reliance on flight

instruments will compensate for this visual disadvantage. Certain improvements to night vision can be effected by understanding and practicing a few basic principles.

11–11. Night Vision

a. To attain night vision, the human eye requires about a 30-minute period of adaptation to darkness. This adaptation may also be accomplished by remaining in a red-lighted

area or by wearing redlensed goggles. Once achieved, night vision should be carefully preserved; even a brief flash of bright light destroys the adaptation. If a pilot must look at the bright light, he should close one eye to preserve its adaptation while the other eye reestablishes night vision. Cockpit lighting should be kept to a minimum; therefore, the pilot must have a thorough "blindfold" knowledge of the cockpit.

b. Because of the structure of the eye, the maximum night perception of a darkened object is obtained by looking slightly to one side of the object rather than directly at it. This is contrary to habitual daytime practice and must be learned by conscious effort. Staring induces blurriness; shifting or blinking the eyes is more effective.

c. Under certain conditions, the visual sense (which is normally the pilot's most dependable sensation) can be adversely affected by vertigo, with possible loss of orientation.

d. Lack of oxygen is harmful to night perception. Supplementary oxygen should be used on night flights above 5,000 feet msl.

e. General physical condition affects night vision. Fatigue, excessive smoking or drinking, and poor eating habits should be avoided.

f. Windshields and windows should be clean and clear.

11–12. Airfield Lighting

a. In general, airfield lighting includes runway lighting, approach lighting, taxiway lighting, obstruction and hazard lighting, beacons, lighted wind direction indicators, and special signal lights. The colors and configurations have been generally standardized on an international scale, with no essential difference between fixed and temporary installations. The basic color code is as follows:

(1) *Blue*—taxiway lighting.

(2) *Clear* (white)—the sides of a usable landing area.

(3) *Green*—the ends of a usable landing area (threshold lights) and, when used with a beacon, a lighted, attended local airfield.

(4) *Red*—hazard, obstruction, and non-landable area.

(5) *Yellow*—caution, and when used with a beacon, seaplane base.

b. Runway lighting is divided into two classes (1) high intensity for IFR operation and (2) medium intensity for VFR operation. Taxiway lights may be supplemented by reflectors.

c. Approach lighting may be used on the primary approach of those airfields intended for instrument flying and all-weather operation. Approach lighting is used only at installations providing precision electronic low-approach facilities. It is never used with medium intensity runway lighting.

d. Special signal lights are used to convey instructions to aviators during radio silence. The following signal lighting is currently used at some military airfields and at civil airfields:

(1) Flashing lights to outline the wind indicator means that the weather is below VFR minimums.

(2) A flashing amber light on top of the tower, adjoining building, or in the center of a segmented circle means that a clockwise flow of traffic is in effect.

e. Standard lighting (which may include use of floodlights) is used for initial night training. Such training is conducted on permanent airfields that provide an approach angle ratio of 50 to 1. Advanced night training is conducted on sod fields with expedient lighting (usually flare pots) arranged similar to Army Supplementary Airfield Lighting Set No. 24, as field configuration permits. Length of the lighted portion of the runway usually is stricted for training purposes, and usu ` glide slope indicator is not used.

(1) Traffic is controlled either b; or standard signal-light gun.

(2) Tactical night training may complished with expedient lighting (ge flare pots) in areas considered operatio: not meeting prescribed glide angle ap clearance. Theater-of-operations portabl ing systems (Set No. 6 and Supplen Set No. 24) are explained in TM 5-£

11–13. Techniques

a. The pilot should be thoroughly familiar with the airplane, its lighting system, and emergency equipment. A red-filter flashlight should always be carried within easy reach in case of lighting failure.

b. All position lights and the battery-generator system must be checked for correct operation. If improperly positioned or too bright, cockpit lights may interfere with outside vision by reflecting against the glass of the cabin enclosure. The position lights should be turned on prior to starting the engine and remain on during engine operation.

c. Night taxiing should be slow and executed with extreme care. Intermittent flashes of the landing lights should be used for clearing and orientation. Care should be taken to avoid the shining of landing lights in the eyes of other aviators.

d. Distance judgment at night is deceptive. For takeoff, the aircraft should be lined up carefully with the runway lights and normal takeoff techniques used. For takeoff from a field without runway lights, a light should be positioned at the upwind end of the field to provide the aviator a reference point for aline-ment and distance. No attempt should be made to pull the airplane off prematurely or prolong its ground roll. Correct takeoff attitude should be maintained until airborne or until takeoff airspeed has been attained. Flight instruments should be cross-checked during initial climb to avoid disorientation as the airport lights are left behind.

(1) The deception involved in estimating distance, altitude, and speed at night makes the approach and landing much more difficult than during daytime operations. Familiar traffic patterns and the 180° side approach are usually used at night. This side approach provides a better view of the lighted area and assures better judgment throughout the approach.

(2) If obstruction lights are available, the pilot may use them in conjunction with the threshold lights to establish a sight picture.

(3) In the absence of obstruction lights, runway lights provide limited aid in judging the approach angle. If the terrain is level and the lights are spaced at a known interval, the problem is simple. Rolling terrain or nonstandard light spacing make the angular reference unreliable. In such cases, the aviator can sometimes take advantage of other reference points in the vicinity of the approach area.

e. Landing lights may be used to aid in seeing unlighted obstructions, although their use may restrict vision during conditions of poor visibility caused by haze, smoke, etc., and their range may be insufficient for the aviator to perceive an obstruction in time to avoid it. The glide angle indicator light is the most accurate and reliable means of approach-angle indication; however, aviators are cautioned not to stare at this light.

f. Night landings can be accomplished using normal power-off landing technique; however, even the most experienced aviator may err in depth perception. The standard procedure involves use of power during the landing flare to maintain minimum flying speed until touchdown. The initial approach may be with power, but care must be exercised to avoid a low drag in. The use of power is essential during dark field landings when ground surface is not visible. It is an effective safeguard against errors in judgment and perception, even on lighted fields. The best night technique is to maintain speed above stalling with power until the wheels touch, thereby avoiding sole reliance on vision.

11–14. Night Flying Cautions

a. In the event of power failure at night, a bailout is advisable rather than attempting to land the airplane. Bright moonlight makes dangerous terrain look deceptively inviting. Exceptions to the advisability of bailing out are (1) a lighted airfield within easy gliding range, or (2) a very low altitude which prohibits bailout.

b. The fading or disappearance of an area of lights is usually a symptom of deteriorating weather. A halo-like glow at the wingtip position lights is an indication of decreasing visibility.

c. The rotating anticollision light (Grimes light) can induce flicker vertigo when reflected

by the propeller disc or by hazy or smoky atmosphere; dizziness and nausea may result.

d. Disorientation happens to the best pilots. An orderly plan for reorientation, based on all the available aids, should be formulated in advance. Such a plan should include calling for outside help before fuel runs critically low.

e. Fuel and engine gages must be checked regularly. Cockpit illumination should be kept low. A vigilant watch for other aircraft must be maintained.

f. High approaches seldom result in anything more serious than a go-around. Low approaches often fail to reach the runway.

Section IV. EVASIVE MANEUVERS

11-15. Contour Flying

Contour flying is the best defense for a light airplane against an attacker from the ground or air. This is low-altitude flying in which the flightpath conforms in general to terrain contours. The airplane presents a poor target because its exposure to ground fire generally is abrupt and of short duration. Furthermore, contour flying conceals landing areas and flight routes from enemy observation.

11-16. Contour Flying Risks

Contour flying involves certain risks which are not common to normal flight at higher altitudes. The aviator must be constantly alert for obstructions, particularly for telephone and power lines. Precarious flight positions, such as abrupt pullups and excessively steep banks, should be avoided; and care must be taken not to lower a wing into ground obstructions, even in gradual banks. Although valleys offer good concealment from enemy observation, if the area is unfamiliar the aviator must assume that wires are strung between the hills. An identical assumption must be applied to any inviting gap between ground obstructions.

11-17. Contour Approach

Benefits gained from contour flying may be lost if a normal approach pattern is used in the landing. The contour approach is employed to offset this disadvantage. For this type of approach, throttle should be reduced far enough from the landing area to dissipate excess airspeed while maintaining altitude approximately equivalent to that used during contour flying. Flaps may be added for further dissipating of airspeed at a predetermined point. As the field boundary comes into view, the pilot should begin a low-altitude power approach.

11-18. Use of Aerial Maneuvers

If attacked by enemy aircraft or ground fire, the only effective evasive action for the Army airplane is for the pilot to make rapid changes in altitude and/or direction; e.g., climbs, split S's and steep diving turns, as altitude permits. Caution must be exercised to avoid obstructions and a high speed stall during the pullout. A turn toward the attacking aircraft will reduce the closure time of the attacking aircraft and be an advantage to the slower Army airplane.

APPENDIX A

REFERENCES

AR 95-series	Army Aviation Series
AR 310-25	Dictionary of United States Army Terms.
AR 310-50	Authorized Abbreviations and Brevity Codes.
AR 715-232	Emergency purchase of Army Aviation Fuels, Oils, Parts, Supplies, Equipment, and Necessary Services From Commercial Sources.
DA Pam 108-1	Index of Army Motion Pictures and Related Audio-Visual Aids.
DA Pam 310-series	(Military Publications Indexes (as applicable).)
FM 1-105	Army Aviation Techniques and Procedures.
FM 21-5	Military Training Management.
FM 21-6	Techniques of Military Instruction.
FM 21-30	Military Symbols.
FM 57-35	Airmobile Operations.
TM 1-215	Attitude Instrument Flying.
TM 1-225	Navigation for Army Aviation.
TM 1-300	Meteorology for Army Aviation.
TM 5-330	Planning and Design of Roads, Airbases, and Heliports in the Theater of Operations.
TM 55-10-series	(Appropriate Aircraft Operator's Manuals.)
TM 55-450-15	Air Movement of Troops and Equipment (Administrative).
TC 1-26	Training on the MK-J5 Martin-Baker Ejection Seat.

APPENDIX B

CARE AND USE OF THE PARACHUTE

B-1. Introduction

The aviator should be thoroughly familiar with the various items of flight equipment before he starts flying, especially those items that are provided for his safety. One of the most important is the parachute. Most of the personnel parachutes used by Army aviators are of the back (A, fig B-1) and chest (B and C, fig B-1) types, each of which has a 28-foot canopy. The airplane to be flown will dictate the type of parachute to be used; however, the back pack is the most common. Without a thorough knowledge of WHEN, WHY, and HOW to use the parachute, it will be of little value as an item of safety equipment.

A — BACK PACK (COMPLETE)
B — CANOPY PACK (CHEST)
C — HARNESS AND PADDING (CHEST)

Figure B-1. Back and chest pack parachutes.

B-2. Back-Type Parachute

The back-type parachute (figs B-2 and B-3) has five main components—

a. *Ripcord Grip Handle.* A handle used to release the pilot chute from the pack.

b. *Pilot Chute.* A chute fastened at the top of the main chute that pops out of the pack by steel springs when the ripcord is pulled. This chute catches the air and pulls the main canopy out of the pack. Without the pilot chute, canopy opening would be slow and the wearer's body might become entangled in the canopy and suspension lines, thereby fouling the chute and rendering it useless.

c. *Main Canopy.* A drag-producing fabric surface that is deployed to slow the descent to the ground; it is secured to the risers by suspension lines. The parachute canopy is of high grade silk, nylon, or pongee. An air vent is pro-

vided at the top of the canopy to help steady the parachute as it settles toward the earth. Without this vent, oscillations would be great and, for the most part, uncontrollable.

d. Risers. Fabric straps secured at one end to the canopy suspension lines and at the opposite end to the harness. Risers control the rate and direction of descent.

★*e. Harness.* That part of the parachute that fits about the body. The harness is constructed principally from type XIII nylon webbing. It can be adjusted to the individual's body with straps, buckles, and fittings. Most of the metal used for the hardware is made from cadmium-plated chrome nickel steel or from polished stainless steel.

B-3. Inspection

Each time the aviator receives a parachute, he should perform a routine inspection of it, just as he performs a preflight inspection of an airplane. This general inspection will indicate whether the chute is in proper condition for use. All visible components of the parachute which may be inspected without opening the pack are inspected, such as webbing, canvas, and hardware. The following checks will be as complete as possible:
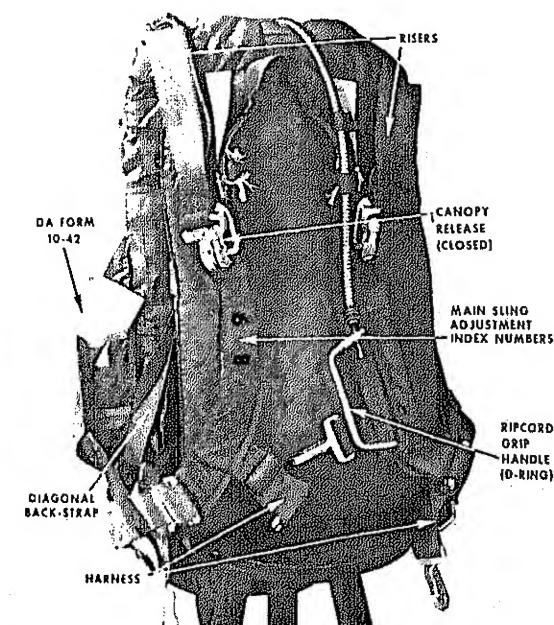
★*Figure B-2. (Superseded) Harness view of parachute.*

a. Note date of repack. Parachutes must be repacked at intervals of 120 days.

b. Check external condition of the pack and harness assembly (fig B-2 and B-3) for defects or deterioration, the stitching and webbing for damage, and the metal fittings for cracks or rust.

c. Check elasticity and attachment of pack opening bands.
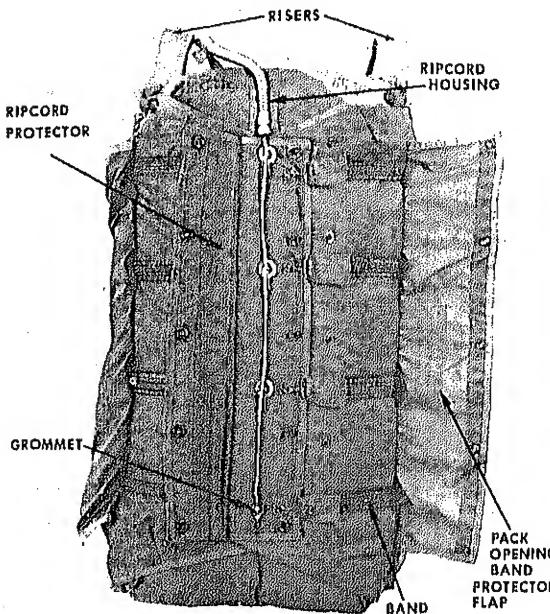
★*Figure B-3. (Superseded) Rear view of parachute.*

d. Open ripcord pin protector flap (fig B-3) and check ripcord pins for proper seating in the cones. Also check to see that pins are not bent or corroded.

e. For back-type parachutes, grasp the harness webbing at a point on the lift web just beyond the ripcord grip pocket and pull against the weight of the pack assembly. Check that pins are not withdrawn by excessive stretch or improper location of the ripcord housing; check ripcord housing for dents or breakage.

f. Check the ripcord grip handle pocket to see that the grip is held securely and protruding enough to be readily accessible. Also check that removal of the grip is not obstructed by misplaced hand stitching.

g. Inspect the canopy release for smooth operation and for damage.

h. Upon completion of the inspection, make

a checkmark in the routine inspection column of the DA Form 10-42 (Army Parachute Log Record), complete the date column, and sign your last name along with your organization in columns provided in the log book.

Note: If, as a result of these checks, conditions are found that indicate a need for repairs or a more thorough inspection, return the parachute to a parachute maintenance shop for complete repair and inspection, regardless of date of last repack.

B-4. Fitting

a. *Tightness of Harness Fit.* After determining that the parachute is serviceable, it should be fitted to the individual who will wear it. When all buckles are fastened, the harness should fit snugly in a standing position (fig B-4).

b. *Strap Adjustment.* For safety reasons, chest and leg straps should be adjusted properly. The chest strap should be snug to prevent the buckle from slapping the user in the face when the chute opens. The main lift web has a chest strap adjustment and a main sling adjustment (fig B-4). The front of the harness webbing has main sling index numbers on it
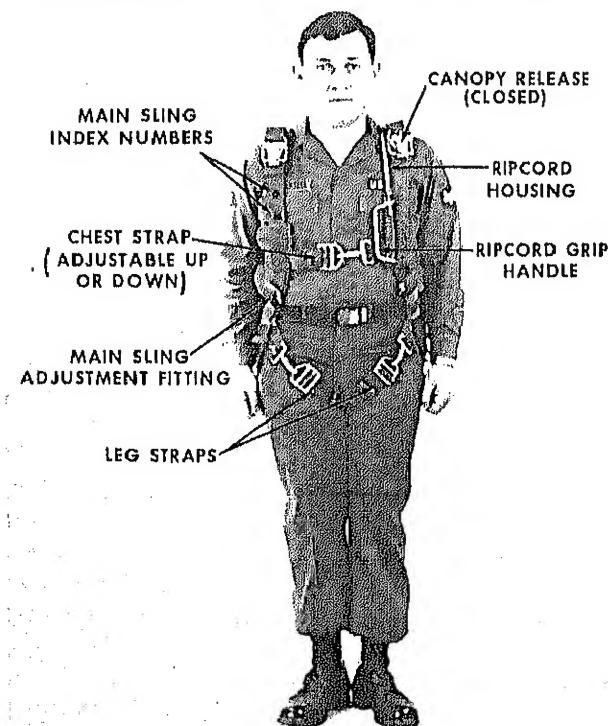
Figure B-4. *Front view of individual wearing back-type parachute.*

(fig B-4). Normally, these numbers can be used as a reference for harness adjustment; i.e., the smaller the number the taller the individual, and the larger the number the shorter the individual. However, if the diagonal back straps (fig B-2) have been adjusted abnormally before you receive the parachute, they will also require adjusting. The chest and leg straps are easily adjusted and permit the user to make a last minute, quick adjustment before bailout.

B-5. Bailout Precautions

Over good terrain, it may be as safe to execute a forced landing as to bail out. This is because of the maneuverability and short field performance of airplanes used in Army aviation. However, there will be times when it is safer to bail out, such as engine failure during night or weather flying, structural failure, or a major fire. If an emergency should develop requiring a bailout, the aviator should make the decision to do so and stick to it. After deciding to bail out, certain precautions should be taken to minimize the possibility of injury. Ability to take precautionary measures will vary, of course, with the time available for bailout and with the degree of flight control. If the airplane is not controllable, exit must be accomplished in the best way the situation will allow. The aviator tries to push himself clear of the airplane and to be sure he actually is clear before pulling the ripcord. The following precautions should be observed to the extent practicable:

a. Slow and trim the airplane as much as possible.

b. Tighten the parachute helmet cord.

c. Disconnect flight helmet cord.

d. Jettison the door.

e. Release safety belt and shoulder harness.

f. Dive outward and rearward, being careful to avoid catching the parachute pack on anything as you leave the cockpit.

g. When completely clear of the airplane, firmly pull the ripcord, being sure the cord clears the housing completely.

B-6. Opening Shock and Descent Precautions

A few precautions can be observed to lessen the opening shock and make the descent as uneventful as possible. These precautions are as follows:

a. Keep your feet together and bend the head forward, putting your chin hard on your chest. This will prevent or lessen injuries which might be inflicted by the opening shock.

b. After the canopy has opened, look up at it. If any of the suspension lines are twisted or across the canopy, manipulate the lines by pulling in an effort to correct the fault.

c. Oscillation during descent is quite normal. Observe drift as quickly as possible, then try to turn to face the direction of drift (fig. B-5). It will then be possible to see the terrain that will be landed on.
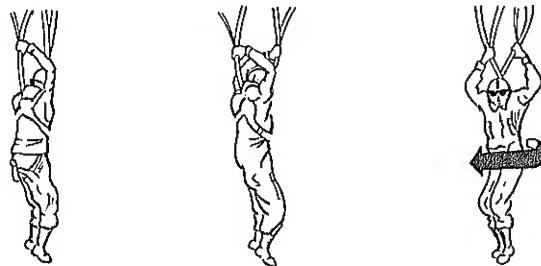
★*Figure B-5. (Superseded) Turning during descent.*

d. It is possible to control the direction of descent to some extent by slipping the chute. To slip the chute, pull the *risers* on the left or right, as appropriate, to cause slipping in that direction. Slipping the chute should be employed only to miss trees, powerlines, or water —if the occasion allows. It should not be at-

˙ ·⊦ from the
ıf drift and
ꜱⱪⱼₚ ꜱₙ ₜₕₑ ₒₚₚₒꜱᵢₜₑ ₐᵢᵣₑᴄₜᵢₒₙ ₍ᵢₙₜₒ the wind). Lock the risers to your chest and press elbows to sides. Keep your head down, chin on chest, and eyes open. Keep your feet and legs together, knees unlocked, and balls of the feet pointed slightly towards the ground. Maintain moderate tension in the legs since they must absorb a major portion of the landing shock.
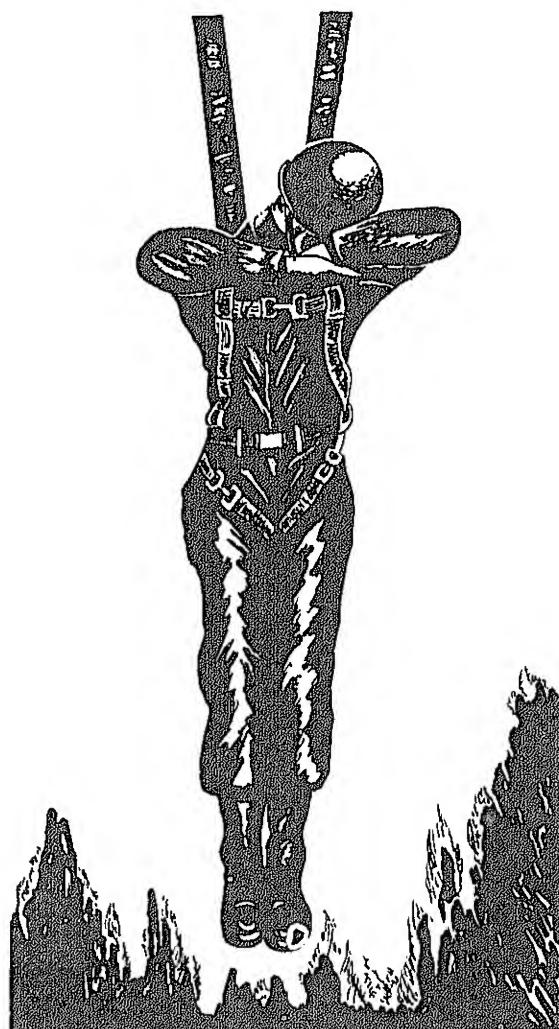
★*Figure B-6. (Superseded) Descent into trees.*

★*f.* Absorb the initial impact on the toes, and then start a fall to the side to allow the rest of the impact to be absorbed by the calf of the leg, thigh, hip, and shoulder. Keep the head down and tension on the neck throughout the fall to keep the head from snapping back and hitting the ground. If there is a high wind, activate the canopy release after contacting the ground to prevent being dragged across the ground. If the releases malfunction, try to get up and run around behind the canopy. If one release functions, the canopy will spill itself but it may drag you a short distance before it does.

g. If it is impossible to miss trees or foliage during descent, keep the feet and legs tight together, and cover the face with the arms

before entering the trees (fig B–6). Be sure a safe descent to the ground can be made before slipping out of the harness.

★*h.* If it is necessary to land in water, activate the canopy release upon touching the water; then start swimming upwind to prevent entanglement in canopy and suspension lines.

B–7. Parachute Care

An Army aviator has a parachute as a safety precaution. Without proper care, it ceases to provide the safety it should and can. Some points to observe in caring for a parachute are—

a. Never leave the parachute where it may be exposed to rain or dew.

b. Do not let the parachute come in contact with any acid, oil, gasoline, or other substance which might tend to weaken or rot the harness or canopy.

c. Do not leave the parachute on its back; lay it on its harness, to prevent bending the locking pins.

d. Handle the parachute carefully to prevent possible disarrangement of the pack which might keep it from opening properly.

e. If anything happens to the parachute which might cause a malfunction, report it promptly so that corrective action can be taken.

f. Treat the parachute with care and respect; it may save a life.

GLOSSARY

Aileron—A hinged control surface on the wing to aid in producing a bank or roll about the longitudinal axis.

Aircraft—Any form of flying machine.

Airfoil—A portion of an airplane which, when moved through the air, is capable of producing a useful aerodynamic reaction.

Airplane—A mechanically driven, heavier than air, flying machine that derives its lift from fixed wing.

Airspeed—The speed of an aircraft in relation to the air through which it is passing.

Altitude—The elevation of an aircraft above a given reference plane.

Angle of attack—The acute angle between the chord of an airfoil and its direction of motion relative to the air.

Attitude—The position of an aircraft considering the inclination of its axes in relation to the horizontal.

Axis—The theoretical line extending through the center of gravity of an aircraft in each major plane: fore and aft, crosswise, and up and down. These are the longitudinal, lateral, and vertical axes.

Bank—To tip or roll about the longitudinal axis of the airplane. Banks are essential to all properly executed turns.

Buffeting—The heating effect of the disturbed airstream on an airplane's structure during flight.

Camber—The distance in the curve of an airfoil section from its chord.

Ceiling (aircraft)—The maximum altitude the aircraft is capable of obtaining under standard conditions.

Center of gravity—The point within an aircraft through which, for balance purposes, the total force of gravity is considered to act.

Chord—The longitudinal dimension of an airfoil section, measured from the leading to trailing edge.

Controls—The devices used by a pilot in operating an aircraft.

Control surfaces—Hinged airfoils exposed to the airflow which control the attitude of the airplane and which are actuated by use of the controls in the airplane.

Coordination—The movement or use of two or more controls in their proper relationship to obtain the desired results.

Cruise control—The procedure for the operation of an aircraft and its powerplants to obtain the maximum efficiency on extended flights.

Dihedral—The upward inclination of a wing from center section toward the tip.

Dive—A steep descent with or without power at a greater airspeed than that normal to level flight.

Drag—Force opposing the motion of the aircraft through the air.

Drift—Deflection (due to wind) of an aircraft from its intended course.

★*Element*—In relation to formation flying, a 2- or 3-plane formation of aircraft.

Elevator—A movable, horizontal control surface used to control the pitch of an airplane.

Empennage—The entire tail group of an airplane, including the fixed and moveable tail surfaces.

Fin—A fixed airfoil which aids directional stability.

Flap—An appendage to an airfoil (usually the wing) used for changing lift and/or drag characteristics.

★*Flight*—In relation to formation flying, a 4-, 5-, or 6-plane formation of aircraft.

Flightpath—The path of the center of gravity of an airplane with reference to the earth.

Fuselage—The body to which the wings, landing gear, and tail are attached.

Glide—Sustained forward flight in which speed is maintained only by the loss of altitude.

Glide angle—The acute angle between the horizontal and downward path along which an airplane descends.

Go-around—A procedure for remaining airborne following a decision to discontinue an intended landing.

Incidence, angle of—The angle between the mean chord of the wing and the longitudinal axis of the airplane.

Induced drag—Drag produced indirectly by the effect of induced lift.

Induced lift—Lift caused by the low pressure of the rapidly-flowing air over the top of an airfoil.

Kinesthesia—The sense which detects and estimates motion without reference to vision or hearing.

Landing—The act of terminating flight and bringing the airplane to rest.

Langing gear—The structure which supports the weight of the airplane while at rest.

Leading edge—The forward edge of any airfoil.

Lift—The supporting force induced by the dynamic reaction of air against the airfoil.

Lift component—A force acting on an airfoil, perpendicular to the direction of its motion through the air.

Load—The forces acting on a structure. These may be static (as with gravity) or dynamic (as with centrifugal force), or a combination of static and dynamic.

Load factor—The sum of the loads on a structure, including the static and dynamic loads, expressed in units of G, or one gravity.

Longeron—The principal longitudinal structural member in a fuselage.

Maneuver—Any planned motion of an aircraft in the air or on the ground.

Monocoque—A type of aircraft construction in which the external skin constitutes the primary structure.

Nosewheel—A turnable or steerable wheel mounted forward in tricycle-geared airplanes.

Orientation—The act of fixing position or attitude by visual and other reference.

Overshoot—To fly beyond a designated area or mark.

Pilot—A person trained to operate the controls of an airplane in flight.

Pitch (airplane)—Movement about the lateral axis.

Pitch (propeller)—The angle of propeller blades measured from the plane of rotation.

Propeller—A device for producing thrust in a fluid, such as water or air.

Pusher—An airplane in which the engine and propeller are mounted facing aft.

Pylon—A prominent mark or point on the ground used as a fix in precision maneuvers.

Relative wind—The motion of the air relative to the airfoil; it is parallel and opposite the flight-path.

Roll—Movement around the longitudinal axis of an aircraft.

Roundout—A change of aircraft attitude and flightpath from that used on final approach to that used for landing.

Rudder—A hinged, vertical control surface used to control movement about the vertical axis.

Rudder pedals—Controls within the airplane by means of which the rudder is actuated.

Runway—A strip, either paved or improved, on which takeoffs and landing are effected.

Skid—Rate of turn is greater than normal for degree of bank established.

Slip—Rate of turn is less than normal for the degree of bank established.

Slipstream—The current of air driven astern by the propeller.

Spin—A prolonged stall in which an airplane rotates about its center of gravity while it descends, usually with its nose well down.

Spiral—A prolonged gliding turn during which at least a 360° change of direction is effected.

Stability—The tendency of an airplane to return to the original flight condition without aid when disturbed.

Stabilizer—The fixed airfoil of an aircraft used to increase stability; usually, the aft fixed horizontal surface to which the elevators are hinged. Some aircraft have been designed with a moveable horizontal stabilizer.

Stall—A condition of an airfoil in which it is at an angle of attack greater than the angle of attack of maximum lift.

Tailwheel—A turnable or steerable wheel mounted at the aft end of the airframe.

Taxi—To operate an airplane under its own power on the ground, except that movement incident to actual takeoff and landing.

Terminal Velocity—The hypothetical maximum speed which could be obtained in a prolonged vertical dive.

Thrust—The forward force on an airplane in the air provided by the engine acting through a propeller in conventional airplanes.

Torque—Any turning or twisting force. Applied to the rolling force imposed on an airplane by the engine in turning the propeller.

Trailing Edge—The rearmost edge of an airfoil.

Useful Load—The difference, in pounds, between the empty weight and maximum authorized gross weight of an aircraft.

Vector—A measurement which has both magnitude and direction.

Venturi or Venturi Tube—A short tube having a large opening in the front and rear with a smaller diameter neck in between. The flow through the venturi causes a pressure drop in the smallest section, the amout of the drop being a function of the velocity of flow.

Vmc—Minimum control speed.

Wash—Air which has been disturbed by the passage of an airfoil.

Wash-in—A greater angle of incidence in one part of a wing.

Washout—A lesser angle of incidence in one part of a wing. (See wash-in.)

Weathervane—The tendency of an airplane on the ground to face into the wind.

Wing—An airfoil which produces the major portion of the lift of an aircraft.

Wing Root—The end of the wing which joints the fuselage or opposite wing.

Wingtip—The end of the wing farthest from the fuselage or cabin.

Yaw—Movement about the vertical axis.

Zoom—To climb for a short time at an angle greater than the angle of maximum climb, the airplane being carried by momentum.

INDEX

By Order of the Secretary of the Army:

HAROLD K. JOHNSON,
General, United States Army,
Chief of Staff.

Official:

KENNETH G. WICKHAM,
Major General, United States Army,
The Adjutant General.

DISTRIBUTION:
To be distributed in accordance with DA Form 12–31, Section I, requirements for operator and crew instructions for all fixed aircraft.